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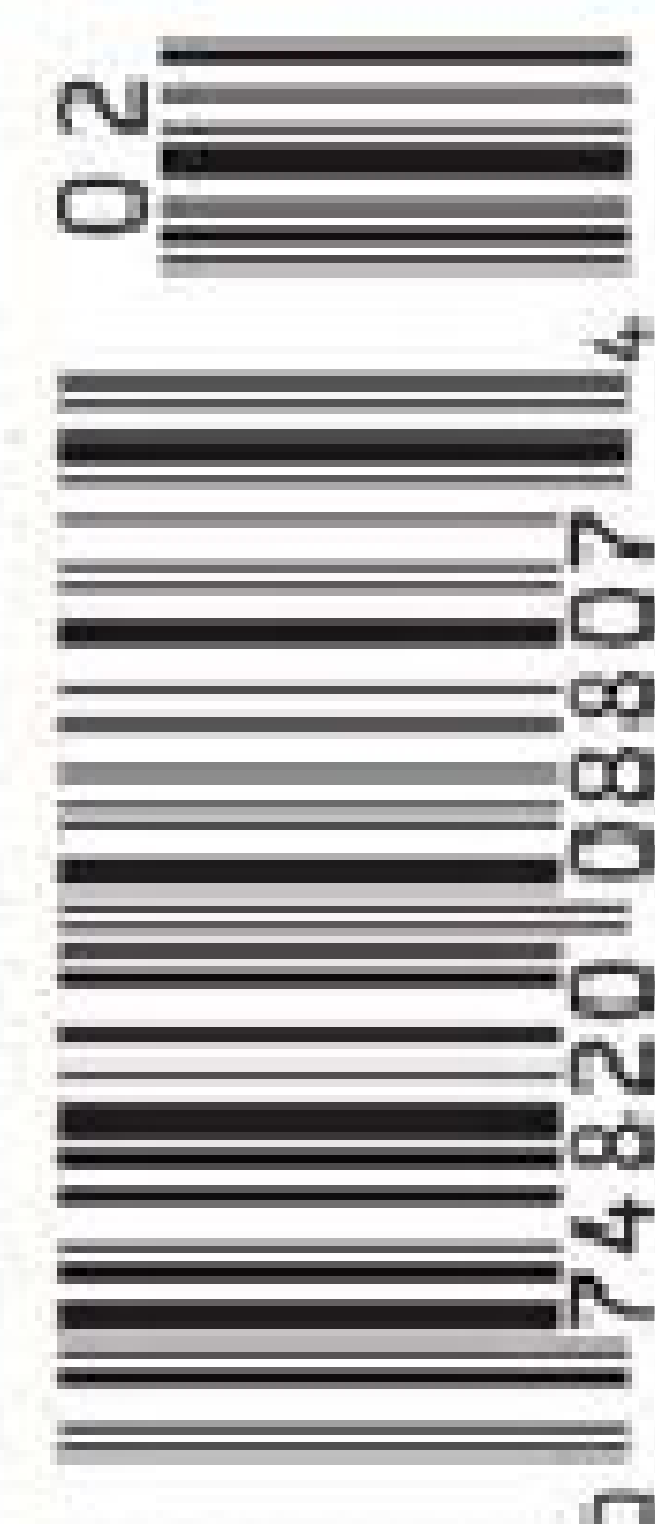
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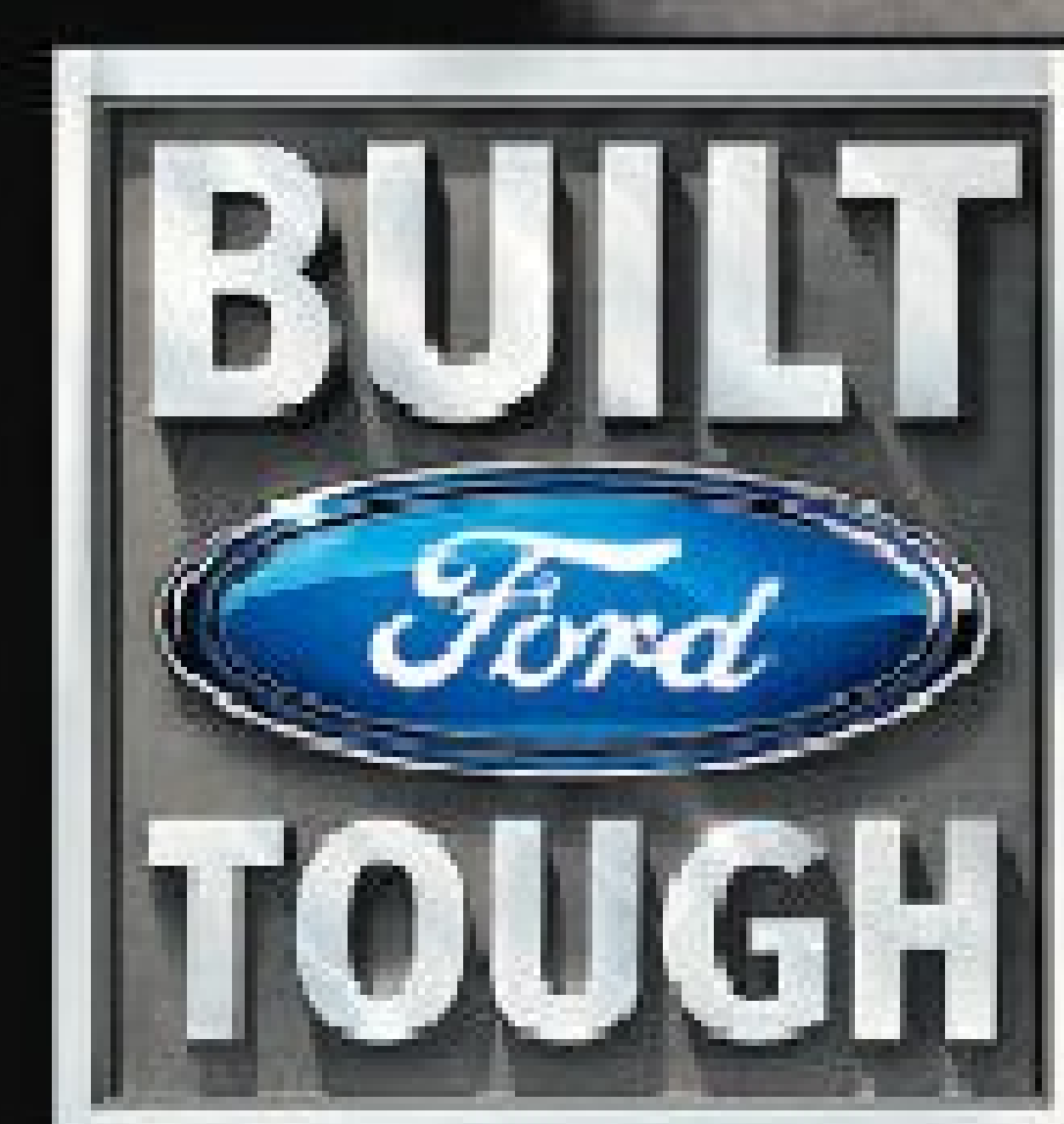




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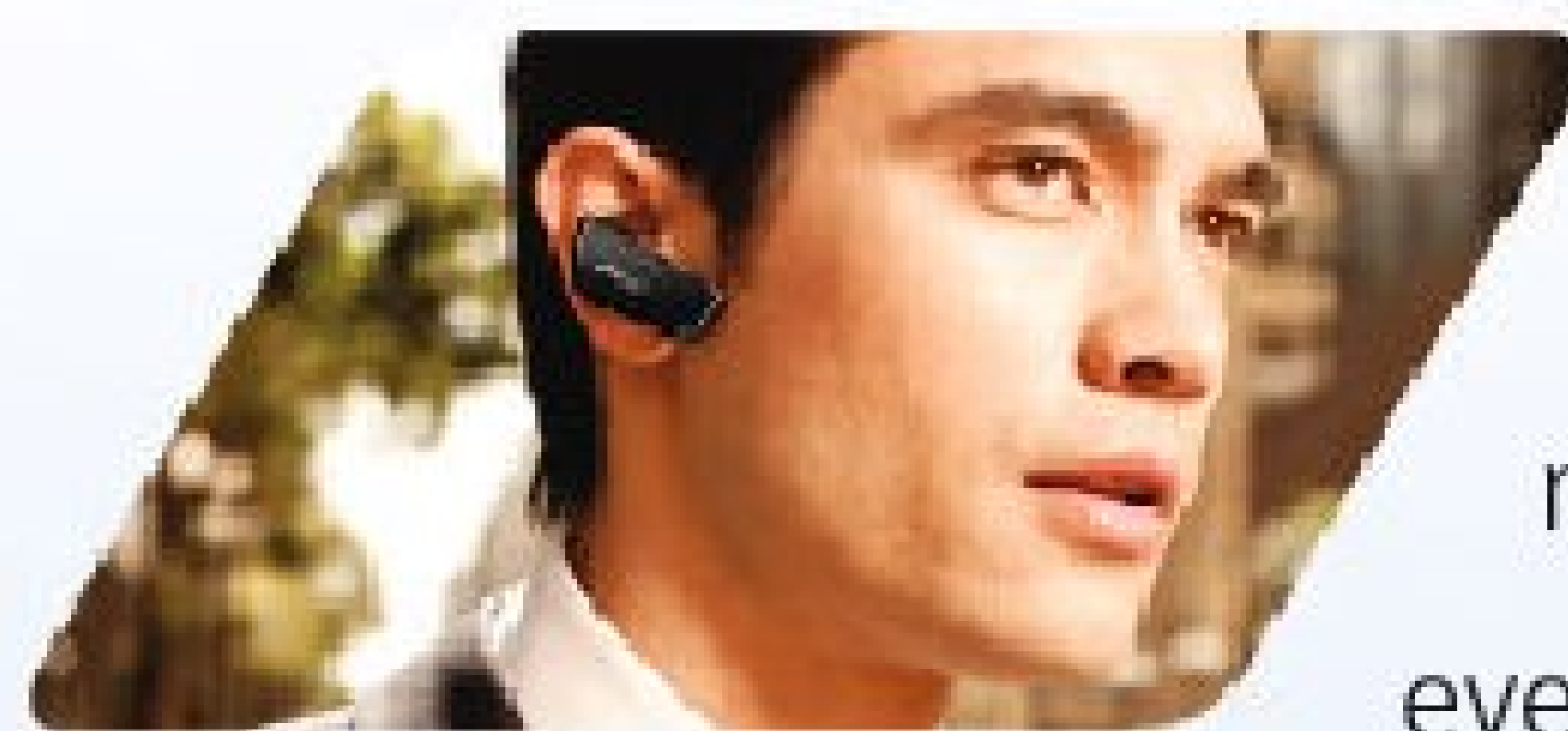
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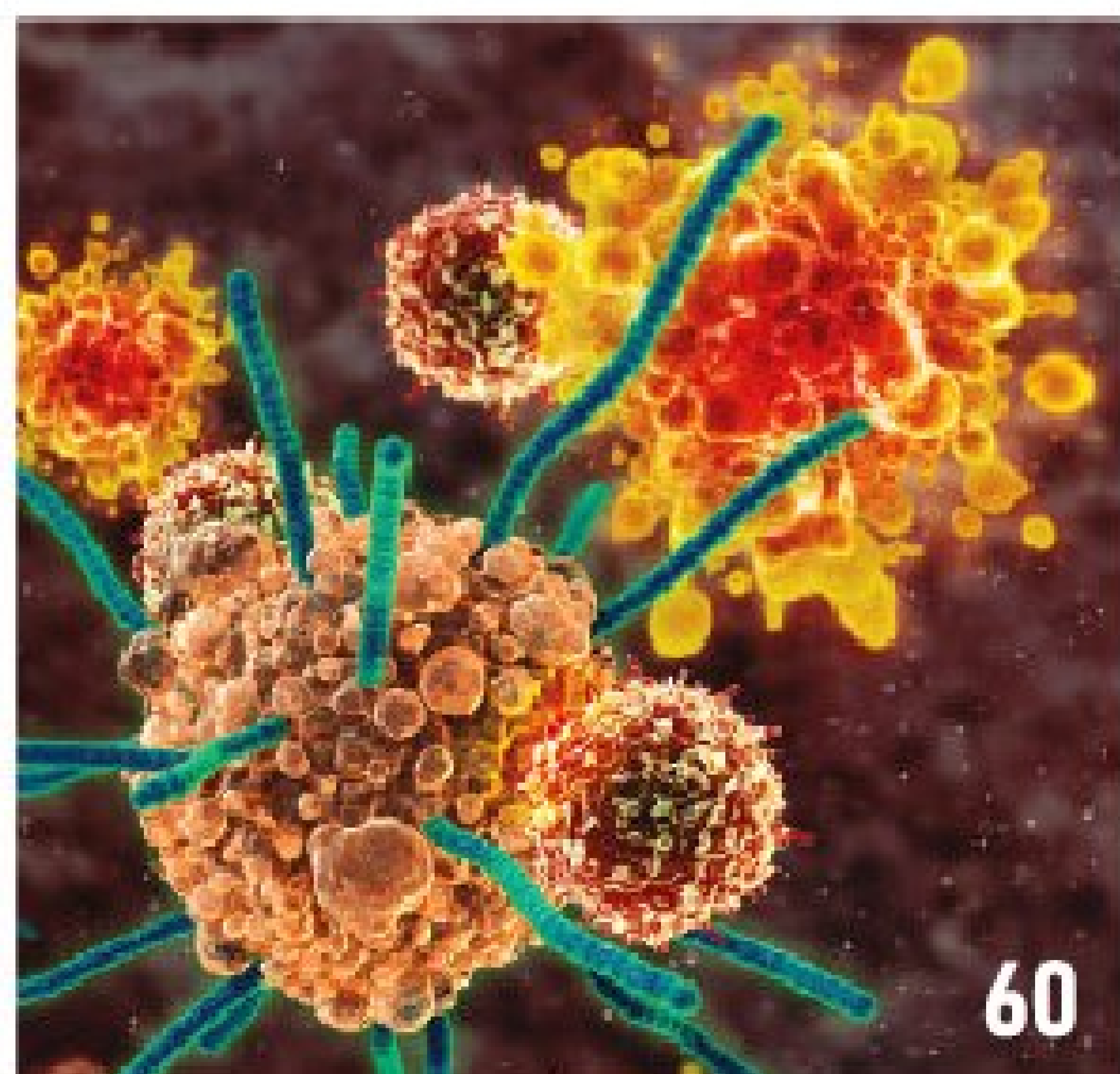
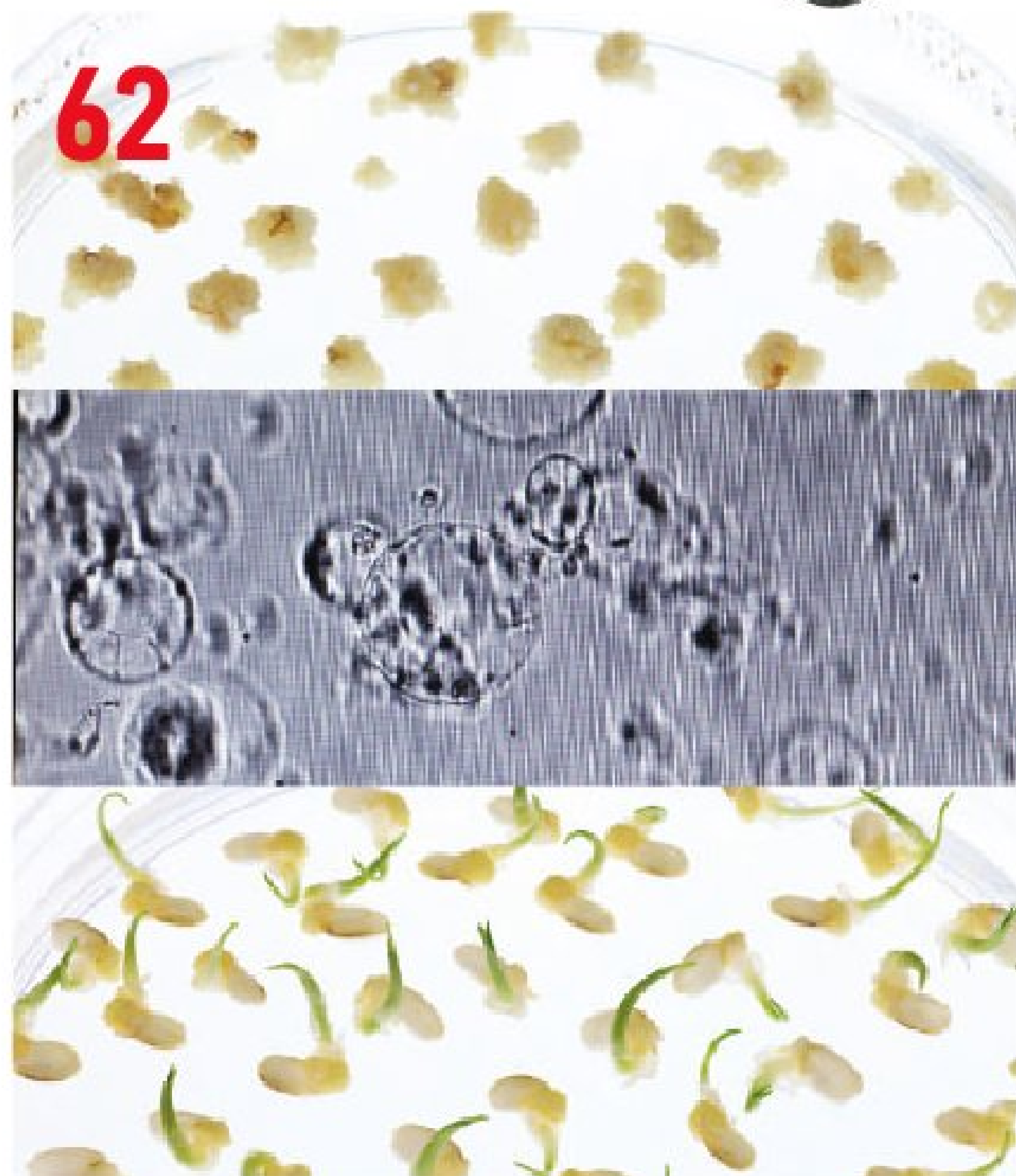
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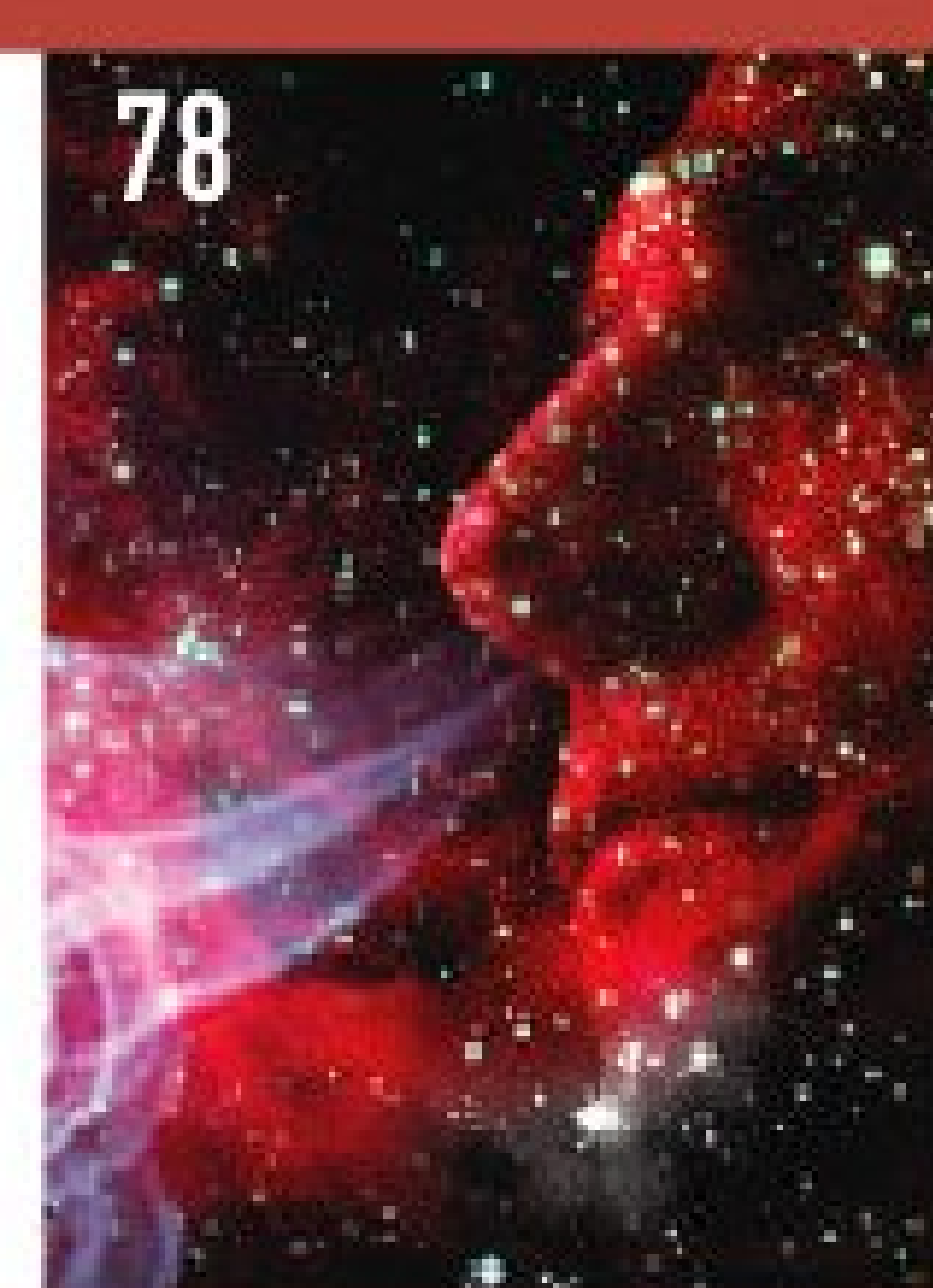
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THE FUTURE NOW



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## FROM THE EDITOR

RECONSIDER  
THE BANANA

**BEGINNING ON PAGE 62** of this issue, you will find an account of an alliance so rare and unexpected that it might strain your credulity, an alliance—a marriage, in fact!—between an organic farmer and a scientist working to genetically modify food plants. In a perfect world, such a partnership wouldn't seem so astounding. But in our world, where polarization is the primary mode of social and political discourse—well, the scientific and marital union of Pamela Ronald and Raoul Adamchak can be a tough one to wrap your mind around.

The Perils  
of Polarized  
Thinking

Of course, the world is never as black and white as our cherished beliefs suggest. All cultivation, organic or otherwise, is an affront to the pure hand of Nature. Yet Adamchak's work shows how organic farming techniques, such as ground-cover crop rotation, can help farmers keep delivering the food we need to support a growing population, even as it reduces our reliance on industrial-grade fertilizer whose production depends (as we often forget) on a rapidly dwindling resource: fossil fuels. As for genetic engineering, it might be the only thing standing in the way of mass starvation.

At one point in the article, Pamela Ronald, the genetic engineer, gestures toward a book called *Banana: The Fate of the Fruit that Changed the World*, and says that a bacterial blight is sweeping through eastern Africa's banana fields. She says that genetic engineering could help immunize bananas against the scourge.

The book Ronald referenced grew out of an article published in this magazine, and its author, Dan Koeppel, is an old friend of mine. So I gave Dan a call to see what sort of perspective he might shed on the prospects for genetic engineering to help save East Africa's bananas. He said it was probably the crop's best shot. In fact, scientists have already begun field trials on a new GMO banana that may resist the blight. "The modified genes in this one are from a green pepper," Dan said. The challenge is in getting that banana from the lab to the marketplace: "You have all these regulations coming from the European Union that penalize countries that allow genetically engineered crops." Meanwhile, millions in Africa face starvation.

The idea that GM food is inherently unhealthy is no less pernicious than the idea that organic, sustainable farming is just a yuppie affectation. Here's hoping that alliances such as the one between Ronald and Adamchak can help put an end to this dangerous strain of dichotomous thinking.

MARK JANNOT

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## THE INBOX

### CONTEST OF CHAMPIONS

Our annual Best of What's New (BOWN) issue [December 2010] crowns 100 items as the premier innovations of that year—and winnowing the list is a process full of heartbreak, spirited argument and cruel choices. But for readers, the list is just the beginning of the discussion.

#### Falcon 9 Needs More Trunk Space

I consider myself an avid fan of SpaceX, but to compare the cost of a SpaceX launch with that of the space shuttle is not comparing apples to apples ["Best of What's New: Aviation & Space"]. On a payload basis, SpaceX's cost is 20 percent *more* than the shuttle. This is a case of larger being more economic.

**Roy\_H**

Comment on [popsci.com](#)

#### I'm Feelin' It

I had the opportunity to try out the KOR-fx, the wearable rumble pack, and it was amazing ["BOWN: Home Entertainment"]. You can really feel what's going on in the game.

**Pando**

Comment on [popsci.com](#)

#### A Very Brief Love Affair

I am a team rider for Hawaiian Pro Designs and was given one of Hydroflex's longboards to test ["BOWN: Recreation"]. I broke it in two days. Hydroflex uses only a single layer of four-ounce fiberglass e-cloth on either side of the lamination, and without a stringer, a board of that size is horribly weak. That's not to say I didn't love it; it was the best surfboard I have ever had, even for the short time I had it. Still, when it comes to pure durability, nothing beats composite sandwich construction.

**ridehpd**

Comment on [popsci.com](#)

#### A Plea for Practicality

The letter from the editor states that the Grand Awards for Innovations of the Year are based on practicality. So how does the half-million-dollar Porsche 918 Spyder win a Grand Award when the Chevy Volt gets only a small blurb ["BOWN: Automotive"]? This revolutionary EV hybrid promises to lead us out of our exorbitant addiction to foreign oil.

**James Melvin**

Via e-mail

BEST OF  
WHAT'S  
NEW  
2010

TOP TECH AWARDS

POPULAR  
SCIENCE

MACH  
10

THE  
FUTURE  
NOW

100 BEST INNOVATIONS  
OF THE  
YEAR



Plug-in supercar:  
The track through  
Porsche 918 Spyder  
hybrid concept

ROAD-READY SPEEDBOAT



PORTABLE OASIS



PERSONAL DRONE



Senior associate editor Seth Fletcher replies: You're right that the Volt is a transformative car; that's why we also gave the Volt concept a BOWN award back in 2007. But for us, the Spyder, with its blend of batteries, electric motors and high-performance internal-combustion technology, was the most pleasant surprise of 2010. It demonstrates that the electrification of the automobile does not spell the end of driving pleasure—in fact, quite the opposite.

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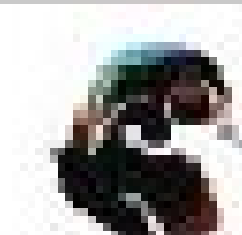
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# MEGAPIXELS

THE MUST-SEE PHOTOS OF THE MONTH

## SURPRISE ATTACK

**Scientists mine dormant bacterial genes for new antibiotics**

*Streptomyces coelicolor*, a soil-dwelling bacterium, has one of the best-understood genomes in its genus. Even so, a computational analysis of its genome has led researchers to a surprise: a new antibiotic compound. By tinkering with the bacteria, researchers at the University of Groningen in the Netherlands were able to awaken an inactive gene group that produces large quantities of yellow coelicolor polyketide and a new compound with antimicrobial activity. The latter compound has proved effective at killing several bacterial strains, including *E. coli*. To produce the antibiotic, scientists identify idle genome segments in the bacteria, isolate the repressor gene that keeps those segments dormant, and delete it from the genome—in effect, switching on the potentially antibiotic-producing segment. The team, led by Eriko Takano, hopes to find compounds that are effective against fungi and cancerous human cells, providing further treatment options for immune-compromised and cancer patients.

BY LIZZIE SCHIFFMAN PHOTOGRAPH BY MARCO GOTTELT



**PIGMENT BEADS ON A BACTERIAL MAT** To get this photo, scientists pipetted droplets of a yellow pigment onto the surface of a *Streptomyces coelicolor* bacterial colony.



## MEGAPIXELS

# POMPEII IN THE PACIFIC

**A volcano's fury overwhelms Indonesia**

Volcanic eruptions aren't just violent; they're incredibly fast, often leaving people no time to flee. Here, a rescue worker walks among the dead in the white-gray ash of Argomulyo, a village in Indonesia. This eruption last November of Mt. Merapi, one of the most active volcanoes in the world, triggered a series of fast-moving pyroclastic flows, a combination of volcanic rock and gas that can reach temperatures of 1,000 degrees. This material barreled down Merapi's slopes at speeds of up to 100 miles an hour. John Pallister, chief of the U.S. Geological Survey-Office

of Foreign Disaster Assistance's Volcano Disaster Assistance Program, worked with the Indonesian volcano-alert agency and credits the country's sophisticated monitoring system and prompt evacuation with keeping the death toll below 350. Otherwise, in such a densely populated place it might have surpassed 30,000. Despite the grisly aftermath, he says, "I think the story here is one of remarkable success and just people doing their jobs right and lives being saved."

BY LIZZIE SCHIFFMAN

PHOTOGRAPH BY ADITIA SURYA







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# WHAT'S NEW

TECH THAT PUTS THE FUTURE IN THE PALM OF YOUR HAND



20

Buick retools the hybrid sedan



22

The fastest everyday laptop graphics



24

A basketball coach on a chip

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**LENS:** 21mm, fixed

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## TRICK SHOT

Compact, ultra-fast image processors power high-quality, shape-shifting cameras

**Camera makers** are reimagining the boxy point-and-shoot. Shrunk sensors allow for crafty designs, while faster processors create shots old models can't match. Casio's slim TRYX is the first of this new breed.

The TRYX is nimble, turning 180 degrees on two axes. Its three-inch LCD spins to show you what's in the shot, be it around a corner or over

a crowd. A frame rotates around the lens to support the camera as a stand, handle or hook.

This lean package, however, holds real power. The brain behind its 12-megapixel sensor creates four-times zoom without a protruding lens and brings out detailed lights and darks—known to pros as “high dynamic range”—

**ARMED AND READY**  
A swiveling arm holds the TRYX steady for a shot.

without Photoshopping. In either case, the sensor combines three rapid-fire shots into a single image, to bring out either background details or a wider color spectrum.

The TRYX opens up many new design possibilities. Such advanced processors could easily wind up in everyday forms like pens and wristwatches.—CORINNE IOZZIO





### Smaller Scrubber

About half the size of earlier models, iRobot's new auto mop is able to wash in tight corners. Instead of using two bins to separate dirty water and clean water, the 'bot has two bladders that expand or shrink as needed. **iRobot Scooba 230** \$300; [irobot.com](http://irobot.com)



### Slight but Tough

This drill weighs under three pounds but can still bore holes in concrete. It's powered by a first-in-class 12-volt lithium battery, which adds oomph without bulk. **Milwaukee M12  $\frac{3}{8}$ -inch Hammer Drill Driver** \$160; [milwaukeetool.com](http://milwaukeetool.com)

### Wrist Twist

The screen of this training watch sits in line with your thumb on the inside of the wrist, so it's always visible while biking or running. A sling under the strap holds it to keep the watch in view, letting it track your time and heart rate in the final sprint. **Timex Ironman Race Trainer Pro Kit** \$200; [timexironman.com](http://timexironman.com)



### Night Shooter

Olympus's new camera is equipped with the fastest lens in a compact, which lets it focus up close in low light. Its autofocus sensor also helps the cause by throwing a soft light on the subject to help pick out and sharpen whatever's up front. **Olympus XZ-1** \$500; [olympus.com](http://olympus.com)



### Data Dock

Secure your info while you charge your iPhone. This charging dock automatically backs up your contacts, photos and videos to a four-gigabyte SD card, so you can quickly restore your data if you lose your handset. **iomega Superhero Dock and Charger** \$70; [iomega.com](http://iomega.com)





## WHAT'S NEW

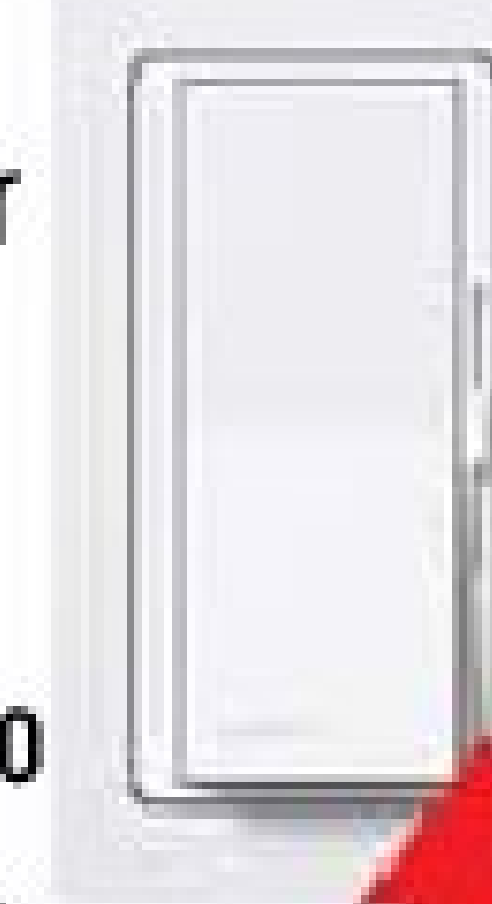
## Camera One, Camera Two

The first HD camcorder with forward- and backward-facing lenses makes taping interviews or reaction shots easy. Switch the feed from front lens to rear with a single button-press for editing on the fly. Omnidirectional microphones on both sides capture audio for each feed. **ION Audio TWIN VIDEO HD** \$200; [ionaudio.com](http://ionaudio.com)



## Lighten Up

Old dimmers can't adjust your new low-wattage CFLs and LEDs. Lutron's model is the only one that can control up to 65 varieties of bulb, thanks to built-in voltage compensation that tweaks output to prevent flickering. **Lutron Diva/C+L Dimmer** \$40; [lutron.com](http://lutron.com)



## Snooze Alert

The dashboard-mounting Anti Sleep Pilot helps make sure you're not driving drowsy. It tracks alertness with intermittent tests, such as measuring how long it takes you to tap it after a beep, to recommend when you should pull over for a rest. **Anti Sleep Pilot** \$250; [antisleepilot.com](http://antisleepilot.com)



## Bright Everywhere

LG's LED-lit HDTV distributes light 20 percent more evenly than others, without adding set-thickening bulbs. Light from its LEDs reflects off microscopic silver particles behind the screen, which ensures that the white level in one area of the screen matches all the others. **LG LW9500** Price not set; [lg.com](http://lg.com)

## Bubble Keeper

Yellow Tail has the first sparkling wine in the U.S. to use the Zork reusable cork, which keeps more fizz in your bubbly than before. Pressing a button reseals the bottle by suctioning out air, while a foil lining traps carbon dioxide inside. **Yellow Tail Bubbles** \$10; [yellowtailwine.com](http://yellowtailwine.com)

THE **goods**  
A dozen great ideas in gear



## Air Play

Stream your iTunes library directly to this speaker and use its remote to browse songs. The setup uses a Wi-Fi connection with your computer and can sync with multiple wireless sets for home-wide audio. **iHome iW1** \$300; [ihomeaudio.com](http://ihomeaudio.com)

## Track Back

Drop this three-inch, 1.7-ounce dongle into anything—your car, your camera bag—and you can track it from a smartphone or computer. Equipped with GPS, cellular and GSM radios, Garmin's tracker lasts up to four weeks on a charge. **Garmin GTU-10** \$200; [garmin.com](http://garmin.com)







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## WHAT'S NEW COMPUTING TECH TREND

## VIDEO POWER

Evolved graphics processing makes laptops HD-friendly

## THE TREND

Slim, light laptops that can play back high-definition video—and edit it—30 percent faster than before

## WHY NOW

Video is becoming harder to manage. The popularity of Blu-ray discs, 3-D video, and high-def camcorders and cellphones means PC users need portable power. So Intel and AMD are cramming graphics processors into the space that normally houses only the CPU. Each 1.5-inch chip can hold nearly a billion transistors, which move and render video data quickly, while a dedicated area handles more-demanding tasks, such as editing high-def footage.

## HOW YOU'LL BENEFIT

Without a graphics processor hogging space and battery power, low-cost laptops, netbooks, all-in-one desktops and even tablets can process high-def video and 3-D while still clocking up to 10 hours of battery life.—JAMIE LENDINO

## ▶ PORTABLE POWERHOUSE

The Pavilion is less than an inch thick and weighs just 3.2 pounds. Its AMD dual-core processor with built-in graphics support easily streams and plays video on its 11.6-inch LCD, a task that used to cripple machines its size.

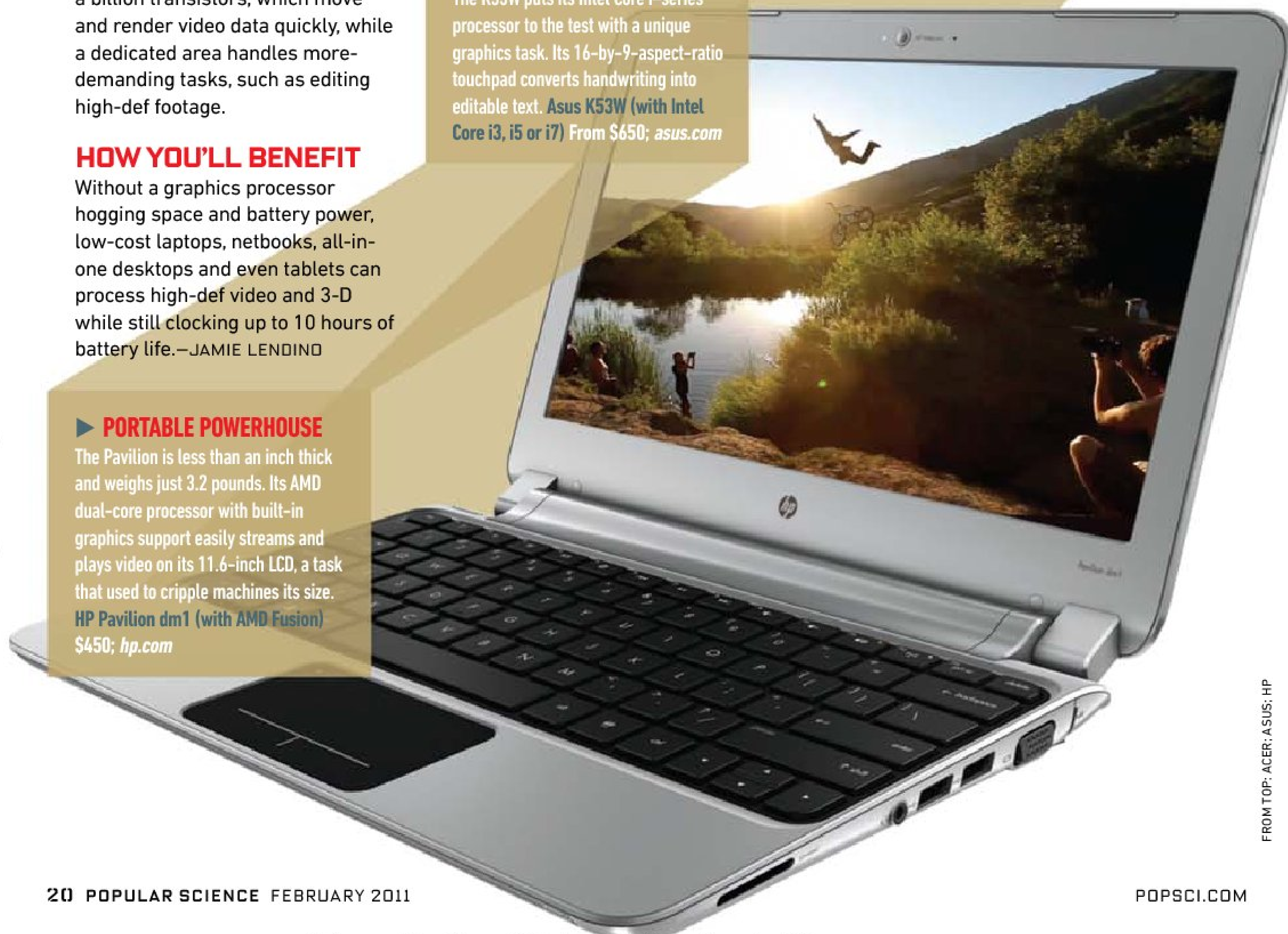
**HP Pavilion dm1 (with AMD Fusion)**  
\$450; [hp.com](http://hp.com)

## ▲ TEXT TWISTER

The K53W puts its Intel Core I-series processor to the test with a unique graphics task. Its 16-by-9-aspect-ratio touchpad converts handwriting into editable text. **Asus K53W (with Intel Core i3, i5 or i7)** From \$650; [asus.com](http://asus.com)

## ▲ MEDIA MOGUL

Even without a separate graphics processor, this Aspire can quickly edit all the high-def video you can fit on its 750-gigabyte hard drive—and then smoothly play it back on its 17.3-inch screen. **Acer Aspire 7745G (with Intel Core i7-2630QM)** \$1,250; [acer.com](http://acer.com)





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## WHAT'S NEW AUTOMOTIVE COMING SOON

HYBRID DRIVE.  
STANDARD

General Motors's eAssist offers hybrid efficiency at no extra cost to the customer

"Mild" hybrids, with their puny batteries and weak electric motors, have largely failed in the marketplace. Next to "full" or "strong" hybrids such as the Toyota Prius—which has a sizeable battery pack and a powerful electric motor and can run under electric power for short stretches—cars like the now-discontinued Chevrolet Malibu hybrid were more expensive than the conventional model but provided only a negligible boost in fuel economy.

With the 2012 Buick LaCrosse, however, GM is launching eAssist, a mild-hybrid system that the company hopes will change that equation. It uses lithium-

**25/37** MPG

25% better mileage than today's four-cylinder LaCrosse

**\$600**

Typical annual gas savings over the V6 model

**65** LBS.

Weight of the eAssist system, which claims 2.4 cubic feet of trunk space

ion batteries to offer a dramatic bump in mileage at a reasonable cost. How reasonable? Beginning this summer, every four-cylinder LaCrosse will feature the eAssist standard. And that hybrid sedan will be priced identically to the base V6 version, starting around \$30,000.

The eAssist-equipped LaCrosse replaces a conventional alternator with an electric motor/generator. Linked to the engine by a drive belt, that motor can help propel the car or generate electricity for the battery. The system shuts off the gas engine at stops, and it can cut fuel to the engine while the car is coasting or decelerating. Powered by a 0.5-kilowatt-hour lithium-ion

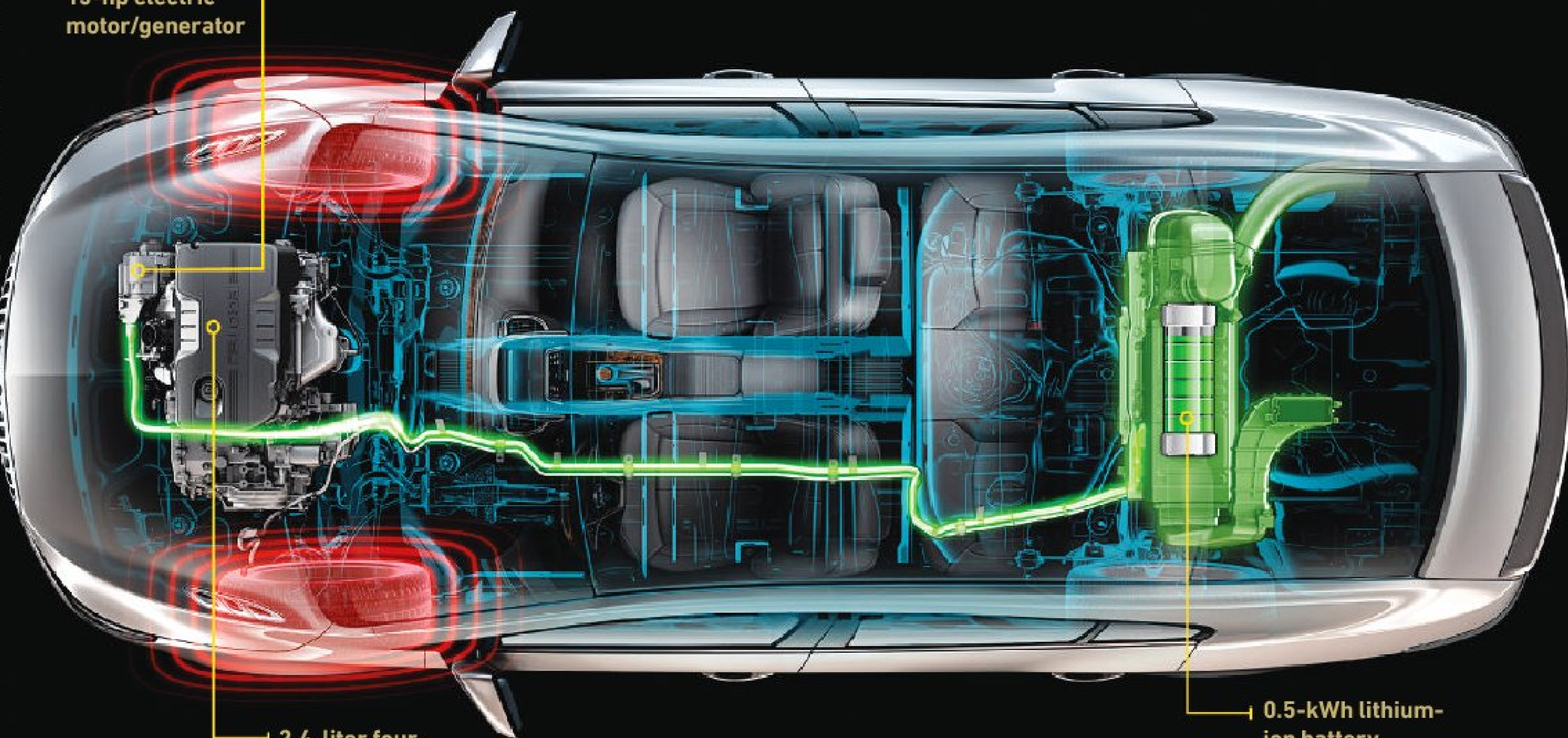
battery, eAssist delivers more than five times the power (a peak 15 horsepower and 110 pound-feet of torque) of GM's previous mild-hybrid technology. That boost lets the Buick's 2.4-liter, 182-horsepower engine run more efficiently without sacrificing performance.

The new LaCrosse will be the market's most efficient full-size sedan, at a GM-estimated 25/37 mpg in city and highway—a 25 percent gain over the current four-cylinder LaCrosse and a leap over the 17/27 mpg of the V6 CXS model. That's enough to save a typical owner approximately \$600 a year on gas, and the price of the car remains the same.—LAWRENCE ULRICH

15-hp electric motor/generator

2.4-liter four-cylinder engine

0.5-kWh lithium-ion battery



ILLUSTRATIONS FROM TOP: DANIEL SCHUMPERT; COURTESY GM



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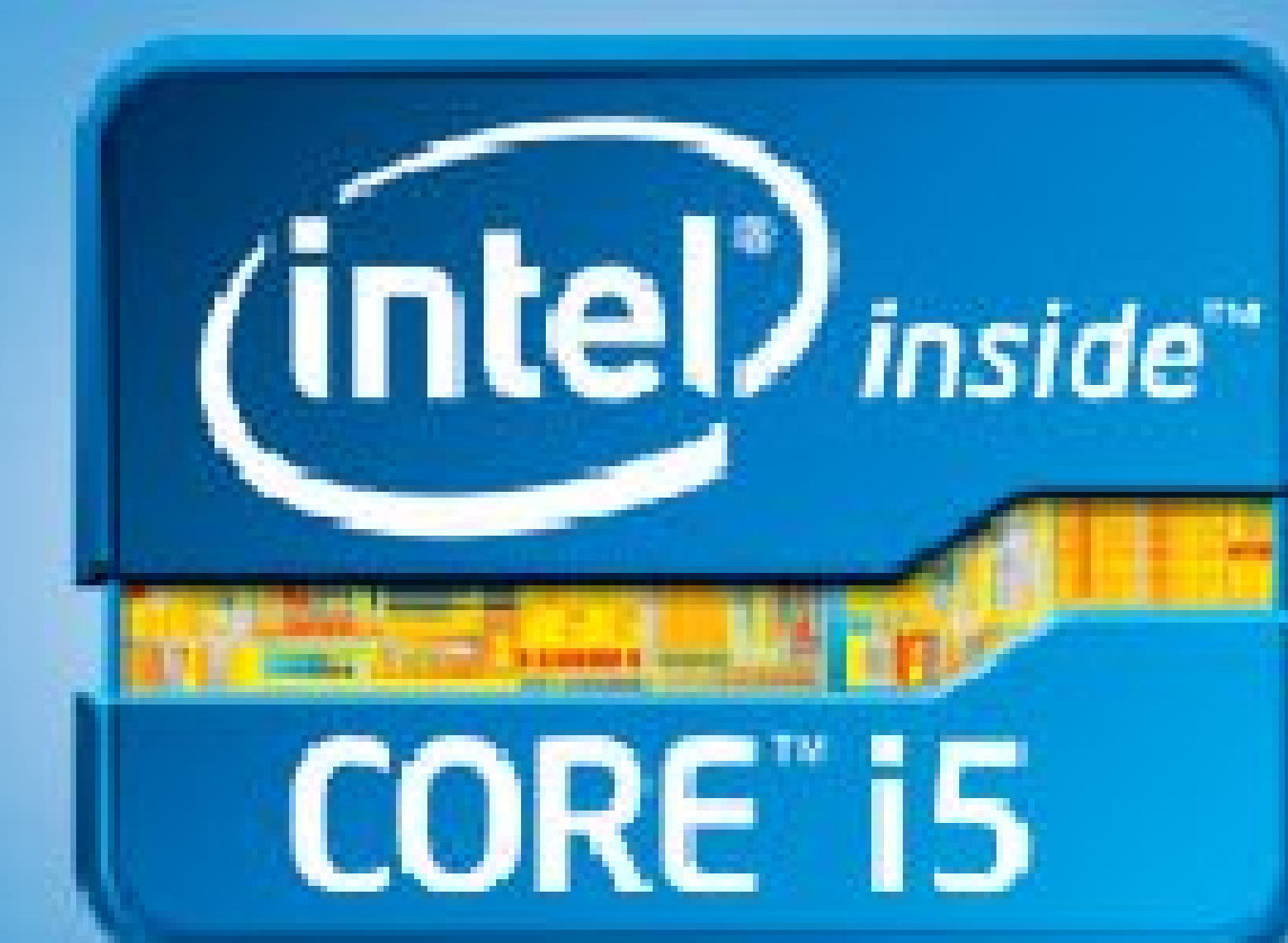
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WHAT'S NEW RECREATION WHAT'S NEXT

# THE AUTOMATIC COACH

A stamp-size sensor embedded in a basketball tracks and evaluates players

MORE INFO:  
InfoMotion  
Sports 94fifty  
basketball  
94fifty.com

**Practice only makes perfect** if you know what perfect looks like. A successful free throw, for example, requires a precise arc, spin and release point, and until now, only a good coach could really spot what was off about a shot. InfoMotion Sports Technologies has teamed with University of Michigan researchers to create a smart ball that assesses shooting skills and ball-handling mechanics. Their five-gram circuit board affixes to the inside of a basketball without altering its flight or bounce. Players run through dribbling or shooting drills while the board gathers data from its accelerometers and gyroscopes. The device wirelessly transmits the data to a computer, which produces a breakdown of each shot and analyzes your performance. This way, you know what you need to work on—say, your right hand needs more dribbling and handling practice than your left.

The system is already being used in youth leagues, as well as at five top-20 college basketball programs. Researchers are licensing the chip to make other sporting goods smart, too. A soccer ball will roll out next year, AboutGolf's club add-on will generate stroke analysis, and baseball-bat makers are looking to break down swing mechanics.—BRETT ZARDA

## IN RELATED NEWS: THE NEW WAVE

**This season**, 10 NBA and NHL teams are revving up their fans with CrowdWave, a large-scale motion-tracking system. Eight high-def cameras on the scoreboard or the rafters feed live images of the stands into software that translates waving into actions. By waving in a prescribed direction, the crowd can answer trivia questions, choose what song plays next, or play interactive games such as *Dance Dance Revolution*. Pro football and baseball teams will also give it a shot later this year. **CrowdWave** [crowdwavegames.com](http://crowdwavegames.com)



GREG NEUMAIER



CONCERT & DANCE

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"PURPLE HAZE"

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playing "LISBON"

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100 NIGHTS"

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## WHAT'S NEW COMPUTING TECH REBORN

## SNAP, DON'T SCAN

A new scanner borrows the brains of a camera for instant imagery

For more than 20 years, flatbed scanners have used slow-moving sensor bars to copy an image by scrolling over documents a little at a time. In replacing that bar with a retooled camera sensor, the Lexmark Genesis captures the entire image in a flash. It can do in three seconds what other scanners take upward of 10 seconds to accomplish.

GET IT:  
Lexmark  
Genesis  
\$400;  
[lexmark.com](http://lexmark.com)

The Genesis has more in common with a digital camera than with a conventional scanner. A 10-megapixel sensor shoots documents through a lens made of six reflective elements, which grab more light to help take clear images even at close range. The sensor grabs six exposures in rapid succession—one each for the

scanner's pairs of red, blue and green flashbulbs—and combines them into a single picture. The image processor on the Genesis corrects the image warping caused by using a wide lens up close.

The process seems nearly instantaneous. Less than a second after the scanner door closes, a preview pops up on the 4.3-inch touchscreen. Within three seconds of hitting the scan button, a full image is ready to print, e-mail, or upload directly to Flickr, Picasa or PhotoBucket over Wi-Fi.

—JOHN HERRMAN

GREG NEUMAIER

Flashbulbs

Image sensor

### MICRO-TREND: SCAN TO THE CLOUD

A new crop of scanners uses Wi-Fi to send docs directly to the Web, sans computer.

### BUSINESS-MINDED

This scanner beams receipts, business cards and more to Google Docs or Evernote. **Fujitsu ScanSnap \$1100 \$200 (est.); [fujitsu.com](http://fujitsu.com)**

### APP-SMART

The eStation talks to the Web with apps, such as one that links directly to a Yahoo account. **HP PhotoSmart eStation \$400; [hp.com](http://hp.com)**

### QUICK-SHARING

The Doxie portable scanner can be programmed to create a 20-character URL for each item. **Doxie \$150; [getdoxie.com](http://getdoxie.com)**



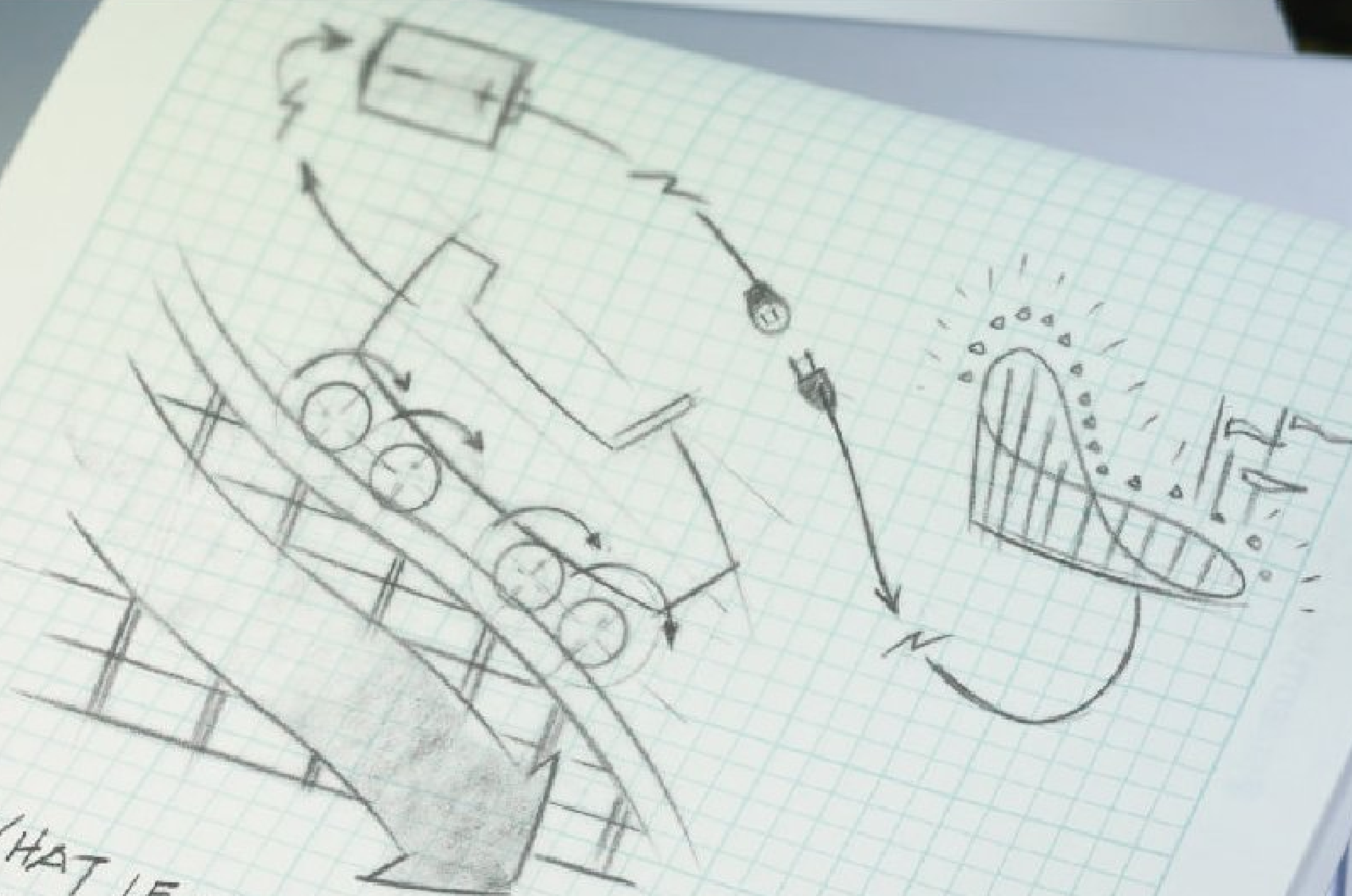
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# WHAT'S NEW FOOD TECH IT'S ABOUT TIME

## HEALTHY AIR

**A new delivery device gets vitamins into the bloodstream faster**

The stomach may be the quickest way to a man's heart, but it's a roundabout way to anyone's bloodstream. That's why Harvard University biomedical engineer David Edwards invented Le Whif breathable vitamins, which get into blood faster than pills do. When you swallow vitamins, your intestinal tract and liver can degrade the active ingredients and also slow their absorption into your body. Breathable vitamins, on the other hand, skip the digestive system and dissolve into the highly permeable tissue lining your cheeks.

To make Le Whif, Edwards (who also pioneered inhalable chocolate, coffee and insulin) ground various vitamins into aerosolized particles, mixed them with different teas to enhance flavor, and packed the mixture into a lipstick-shaped inhaler that you draw on like a pipe to pull the particles out. A plug at the end of the device directs the vitamin spray upward and prevents the mist from shooting down the throat and making the user choke.

The manufacturer Breathable Foods sells three varieties: green tea with vitamins C and E, hibiscus tea with a multivitamin, and wine tea, which delivers vitamin D and 20 milligrams of resveratrol, a compound found in the skin of red grapes that may fight cancer and inflammation. Eight inhales a day supply 100 percent of the daily dose of each vitamin.

Edwards's team is exploring other edibles, too. Food substitutes, he says, provide flavor without adding calories, satisfying cravings in a healthy way. Mmm, huffable mac 'n' cheese.—NICOLE DYER

**GET IT:** Le Whif Vitamins  
\$34/pack of 18;  
[lewhif.com](http://lewhif.com)

### HOW TO WHIFF



Hold the tube on its side, and pull from both ends to open.



Place the slotted end just inside your lips, and inhale gently.



Snap closed. You have seven more whiffs left for your full dose.

CLOCKWISE FROM TOP: PAUL WOOLTON; COURTESY LE WHIF; COURTESY BENJOY



### IN RELATED NEWS: UNSPILLABLE SNACKS

Worry no more about potato-chip crumbs grinding into your living-room carpet. A new line of snacks from British company Benjoy are the first spill-proof single-serve munchies. Rather than using a replaceable lid, Benjoy stretches a semi-rigid polyester membrane 50 microns thick (about half that of a sheet of paper) over the mouth of the cup. The layer is crosscut so you can reach in to grab a piece of dried fruit or a veggie chip, but it's elastic enough to spring back into place and reseal the cup. Look for similar snacking tech in the U.S. soon. **Benjoy Munchcups** [benjoy.co.uk](http://benjoy.co.uk)—NATALIE WOLCHOVER





# CHANGE YOUR EXPIRATION DATE.



## A healthy history.

For thousands of years, pomegranates have been recognized for their contributions to health and well-being. To the ancient Persians, they offered the promise of invincibility. To the Greeks, pomegranates symbolized fertility. In ancient Egypt, King Tut was entombed with a pomegranate-shaped vase. So why did so many civilizations hold the pomegranate in such high esteem?



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concentrated that just one 1000 mg capsule has the antioxidant power of a full glass of POM Wonderful juice.

## The power of POMx.

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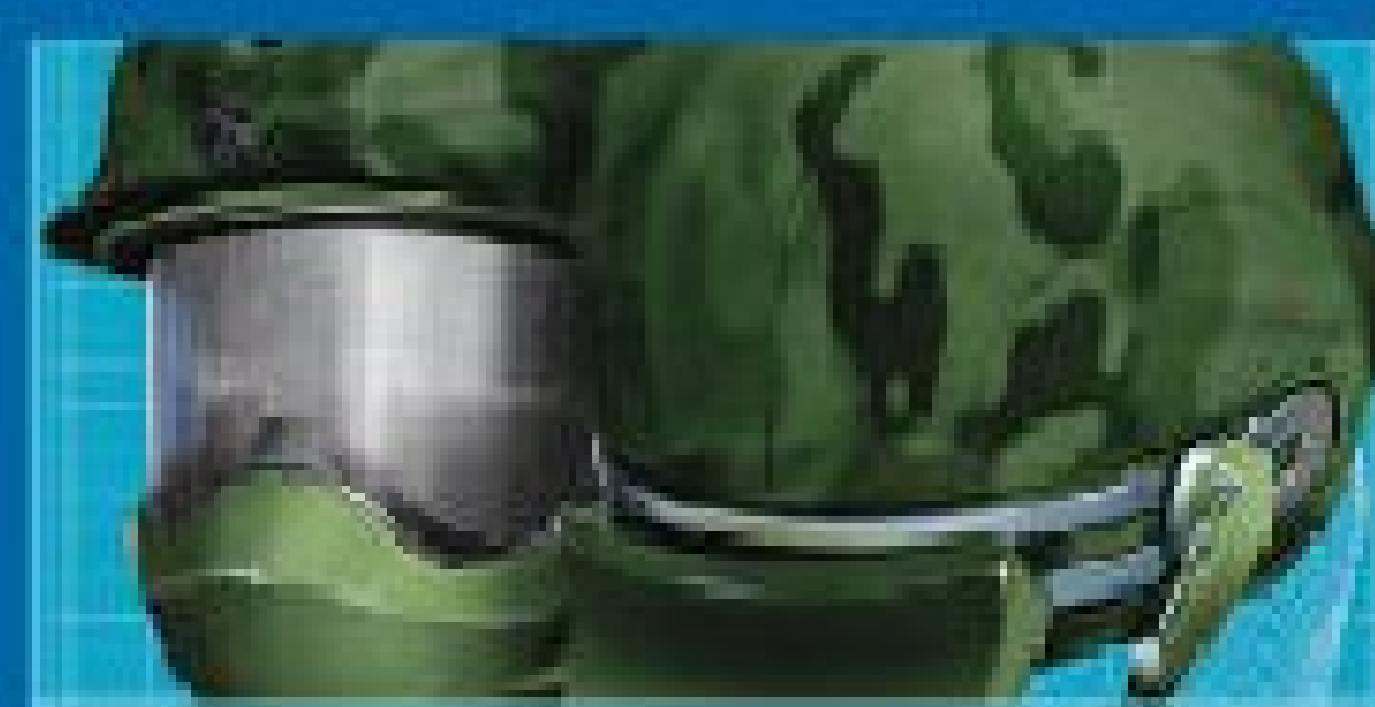


**GET CONNECTED**



# HEADLINES

DISCOVERIES, ADVANCES AND DEBATES IN SCIENCE



**34**  
The army helmet gets shockproofed



**36**  
Sheep that eat TNT



**41**  
Our brain, reverse-engineered

## INFRASTRUCTURE

# SQUEALING SAVIORS

Robots called PIGs keep gas lines from blowing up. This new little piggy goes where the rest can't

When a natural-gas line exploded late last summer in San Bruno, California, the ensuing firestorm raged for hours. The blaze, which took crews more than 12 hours to control, destroyed dozens of homes, injured more than 50 people, and killed eight.

The National Transportation Safety Board's final report on the cause of the blast is still pending as of press time, but the incident has thrown a spotlight on the natural-gas industry's inadequate pipe-inspection techniques. Gas-transmission-line accidents increased 72 percent from the 1990s through the '00s, according to the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. Since the 1960s, maintenance workers have used "smart" pipeline inspection gauges, or PIGs, to find rust, weak seams, thinning walls and other indicators that a pipe needs repair or replacement. As befits their name, PIGs make a squealing sound while navigating tight passageways.



### THE NEW PIPE PIG

The Explorer-II's camera images [above left] and magnetic sensors spot pipe damage, preventing disasters similar to the firestorm in San Bruno this summer [above].

They go where people can't, but controlling them can be challenging because most depend solely on the pipe's pressurized fluid for propulsion. "It's very difficult to stop a PIG in one location," says Karl Edminster, the head of Electromechanica, a Massachusetts firm that manufactures PIGs and other robotic pipe-inspection devices. "Imagine pushing a spitball through a straw." Moreover, nearly a third of the

**FOOTNOTES** **REAL FEEL** Microsoft filed a patent for tactile touchscreens that will simulate the feel of real buttons by using shape-memory plastic to create texture.



## HEADLINES INFRASTRUCTURE

## PIGGING THE UNPIGGABLE

The Explorer-II is a wireless, remotely controlled, wormlike robot that can cruise through miles of gas pipeline on a single charge, beaming image and sensor data back to its operator in real time. It's narrow enough to squeeze through a six-inch-diameter pipe and flexible enough to wind around 90-degree pipeline bends. Here's how it works.

**EXPLORER-II****Length:** 8.3 feet**Weight:** 66 pounds**Battery life:** 8 hours**Inspection speed:** 4 inches per second**Development cost:** \$1.5–\$2 million**Wireless range:** At least 1,000 feet**SONDE COILS**

Two sonde coils generate magnetic fields that allow operators to detect the robot's location so it can be retrieved if the system fails.

**DRIVE MODULE**

The robot's two fist-size brushless motors, one at each end of the robot, let it move independently of the natural-gas flow inside the pipe.

**ONBOARD COMPUTERS**

A suite of onboard computers, controlled by the robot's two 32-bit nerve centers, direct an array of essential functions, including steering, video processing, leg expansion and retraction, and wireless communication.

**HIGH-FRICTION WHEELS**

Inch-wide urethane wheels push out against the pipe's walls, giving the robot enough traction to climb straight up even vertical pipelines.

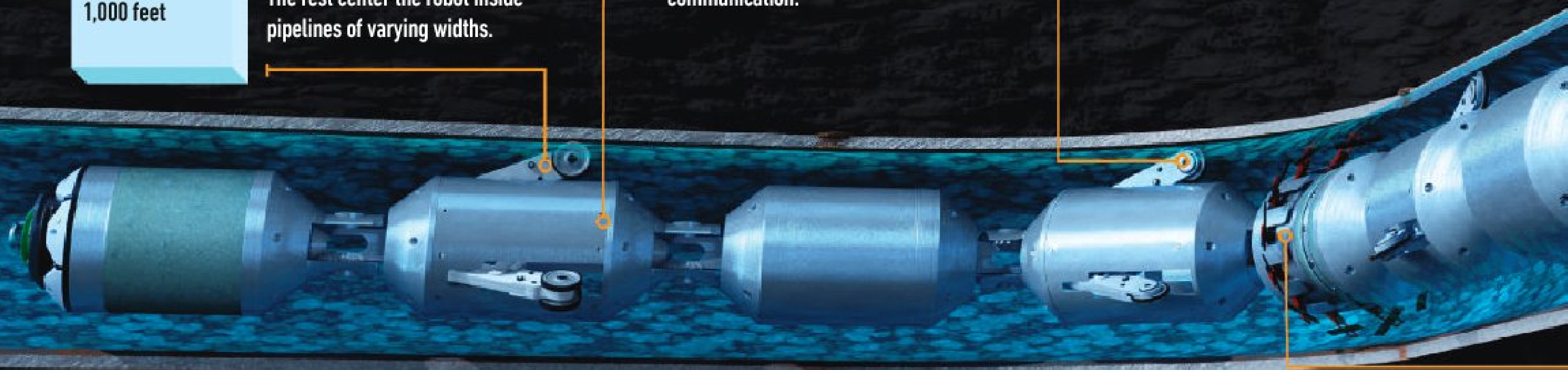
**LITHIUM-POLYMER BATTERIES**

Packed tightly inside the robot's power modules, the batteries allow inspections to last eight hours or more—very important given the thousands of miles of pipeline that need to be vetted on a yearly basis. A crew equipped with a single Explorer-II could inspect as much as two miles in a day.

**LEGS**

Of its 15 legs, six have powered wheels and can extend and retract. The rest center the robot inside pipelines of varying widths.

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1.3 million miles of natural-gas pipeline in the U.S. are "unpiggable." Some pipes widen and then narrow; others have bends too acute to be navigated by current PIG technology. As these pipes age and corrode, the need to inspect them is increasingly urgent. Roughly 60 percent of gas-transmission lines in the U.S. were installed before 1970, and some date back to the Great Depression. Utilities are gradually upgrading

from old cast-iron and steel pipes to non-corroding plastic ones. Even so, it's still far more cost-effective to PIG a pipe than install a new one.

To Carnegie Mellon University roboticist Hagen Schempf and his colleagues, the opportunity to prevent disasters by building a more sophisticated inspection device was too good to pass up. After 10 years of research, and with about \$1 million in funding from NASA and the

**THE ROBOT  
DETECTS TINY  
ANOMALIES IN  
PIPE WALLS  
BEFORE THEY  
TURN DANGEROUS.**

GRAHAM MURDOCH

**STAR PARTY** Astronomers found new clusters of red-dwarf stars, tripling the number of known stars in the universe.



## FISH-EYE CAMERAS

Conventional PIGs can't handle sharp bends because they can't navigate. The Explorer-II's fish-eye cameras—one at each end—have a 190-degree field of vision and send a constant stream of visual data 1,000 feet to the operator, who steers the robot. The cameras also let the operator detect potential damage, such as corrosion or failing seams.

## JOINTS

Capable of 90 degrees of articulation in any direction, the robot's joints give it the freedom of movement it needs to pass through sharp turns and bends inside pipeline systems.

## CURRENT SENSOR

The robot's dynamic electromagnetic coil creates a magnetic field in the pipe, which the 'bot then measures. Minor variations in this magnetic field indicate differences in the thickness of the pipe's walls, a sign of possible damage or corrosion.

U.S. Department of Energy, Schempf recently debuted the Explorer-II: a 66-pound, eight-foot-long wireless robot that he describes as looking "like a series of sausage links." Its segmented body navigates twists and turns with ease. Its strong drivetrain lets operators precisely control where it starts and stops, instead of being moved by the flow of natural gas like other PIGs are. And its custom-designed sensors detect

tiny anomalies in pipe walls before they turn dangerous. Conventional PIGs use permanent magnets to detect changes in the pipe walls' magnetization that may indicate corrosion, but the magnetic field interferes with the PIG's movement, slowing it down. The Explorer-II replaces permanent magnets with a compact electromagnetic coil that senses the same problems without sacrificing speed.

The robot recently proved its grit in Pennsylvania, snaking through 2,000 feet of previously unpiggable pipeline, and it's now in commercial trials with a Canadian gas company. "There was a lot of gulping until we felt comfortable that we had a safe design," Schempf says. "We built this for a dangerous, explosive environment, and that was always in the back of our minds."

—ELIZABETH SVOBODA

**BEE NAV** Australian researchers developed an autopilot system modeled on honeybees' flight and, after testing, found it worked better than gyroscope-based systems.



# HEADLINES DEFENSE TECH



## POSSIBLE FEATURES

**HEAD-UP DISPLAY** An updated version of the Land Warrior system already in use would show maps, locations of fellow soldiers and enemies, computer-aided weapons sighting and alerts from commanding officers.

**COMMUNICATION** Earbuds would automatically reduce sounds louder than 85 decibels to safe levels. A microphone would relay outgoing radio transmissions.

**FACE SHIELD AND INTEGRATED MANDIBLE PROTECTION** These guards would deflect energy from a blast wave away from the eyes, nose and mouth.

**SHOULDER-MOUNTED EXOSKELETON** The harness could support the added weight from the mask and prevent the head from snapping forward or side to side. The Army is also investigating a retractable option that would give full maneuverability when the harness isn't needed.

# SHOCKPROOF

Next-generation Army helmets draw inspiration from Nascar and *Star Wars*

**Improvised explosive devices** are one of the biggest threats to soldiers in Afghanistan and across the world. They unleash a shock wave that can travel about 1,000 feet per second and hit with a pressure of 100 pounds per square inch. The U.S. Army's standard-issue Kevlar combat helmet absorbs some of that force, but it isn't designed to protect the soldier's face from shock waves, which studies suggest can pass through the eyes, nose and mouth to the brain. Nor does it prevent a soldier's head from jerking around, which can cause brain damage. Fortunately, Army researchers are exploring new designs that could someday

**CHARGED UP**  
About 800 IEDs are found in Afghanistan every month.

protect troops from these hazards.

Helmets of the future will probably enclose the head for better protection, says Kenneth Curley, the physician coordinating the Army's neurotrauma research while keeping tabs on other teams. Adding a face shield to combat helmets would cut about 80 percent of the pressure on the front of the brain, according to a software blast model published by Massachusetts Institute of Technology aeronautical engineer Raúl Radovitzky and his colleagues. Don Lee, the project officer of the "HEaDS-UP" Army Technology Objective, is developing shields for the face and other

helmet technologies, which should be ready for review by 2013.

Other researchers are working on a customized shoulder-mounted harness to protect the head from whipping forward or twisting sideways. An Army analysis concluded that a Nascar-style head-and-neck system would restrict soldiers' vision too much, so Shawn Walsh of the Army Research Lab is designing one that won't inhibit movement or vision. A fully functional demonstration harness should be ready this winter.

Because many soldiers choose comfort over safety, Walsh will pay special attention to soldiers' complaints during testing. "Have you ever put on one of those costume Stormtrooper helmets?" Curley asks. "They're not very comfortable, and you can't see well or move your head around. We've got to strike a balance between practicality and the proper protection."

—ANDREW ROSENBLUM

**NOT QUITE ALIEN** Biologists modified a bacterium to use arsenic in its DNA, reminding astrobiologists that life on other planets could work differently than it does on Earth.



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## HEADLINES ENVIRONMENT

# BAA, BAA BLAMMO!

To clean up explosives residue, go with these grazers



A team of scientists is feeding TNT to a flock of sheep. A. Morrie Craig, a veterinary scientist at Oregon State University, has found that the cud-chewing mammals can efficiently clean up explosives-contaminated soil, of which there are 1.3 million tons throughout the U.S.

TNT and other explosives from military munitions training and the remnants of old factories remain in the ground for decades. This residue rarely poses an immediate health threat, but officials at the Department of Defense fear that it could seep into groundwater or poison plants (which has happened

### TOUGH GUT

The bacteria in a sheep's stomach can save its life. The tansy ragwort weed kills cows, but sheep's superior bacteria break down the poison and keep their woolly host alive.

before). Conventional cleanup techniques, such as incinerating the soil, are expensive and time-consuming. Sheep will work for free.

In 2004, Craig discovered that the bacteria in a sheep's stomach that help digest cellulose can also rapidly convert TNT into a harmless compound. In recent experiments, he and researchers from the U.S. Department of Agriculture fed sheep TNT for three weeks and found that it broke down so completely that no traces of it or any related compounds remained in the animals' feces.

Craig and his colleagues plan to plant grasses in TNT-contaminated

soil to suck up the explosives. While the sheep munch away, the bacteria in their digestive tract take care of the rest. Craig's lab is testing the grazers on soil from a military base. He estimates that a flock of 20 could clear an acre of grass in a month, and completely rid it of munitions residue in less than three years.

Craig points out that even if a TNT-eating sheep's meat found its way onto a barbecue, it could never explode or cause health problems: "The ingested TNT is broken down into small molecules that are in no way similar to the original compound."—JONATHAN PARKINSON

## HEADLINES MEDICINE

# A HEALTHY GLOW

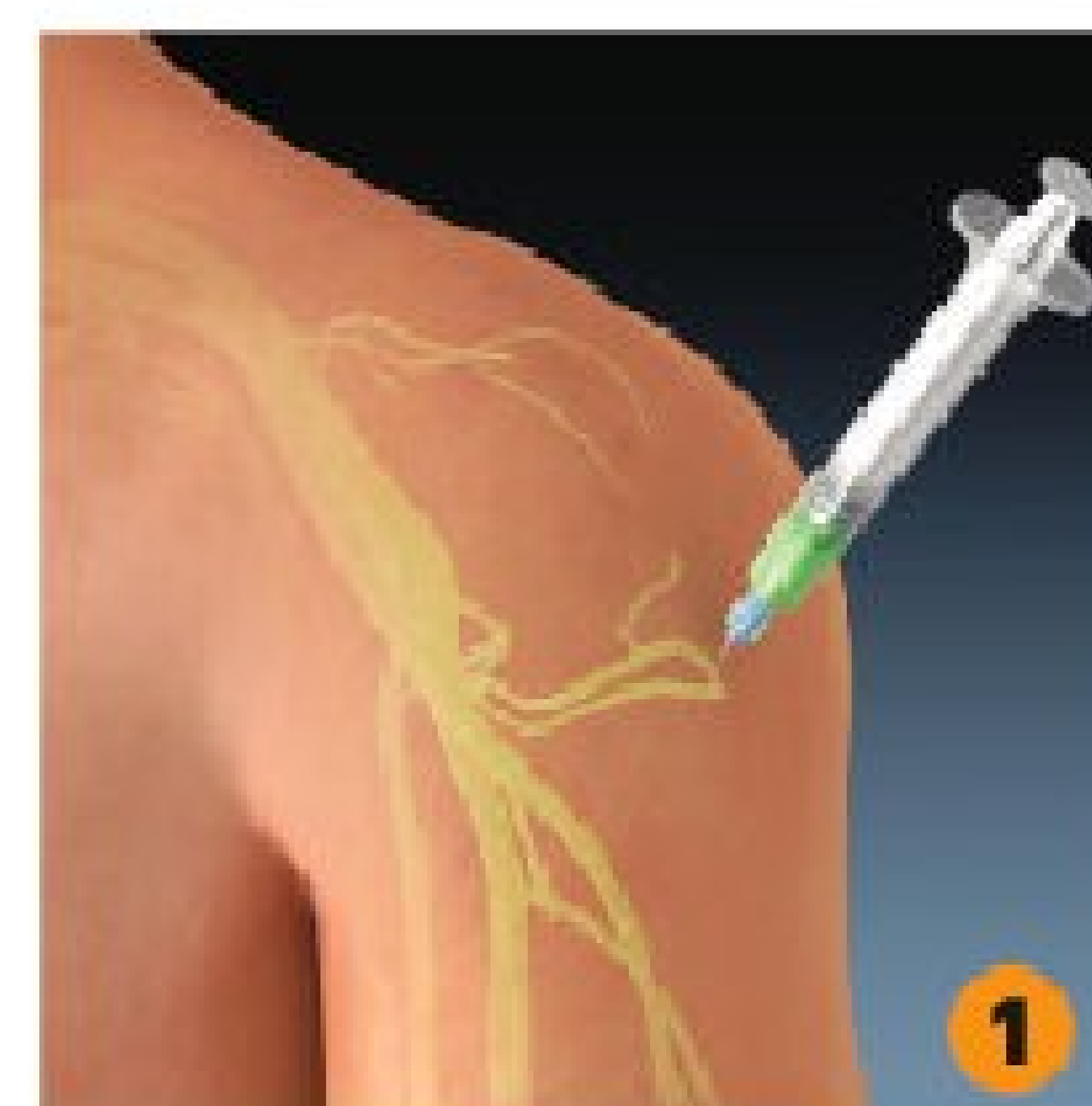
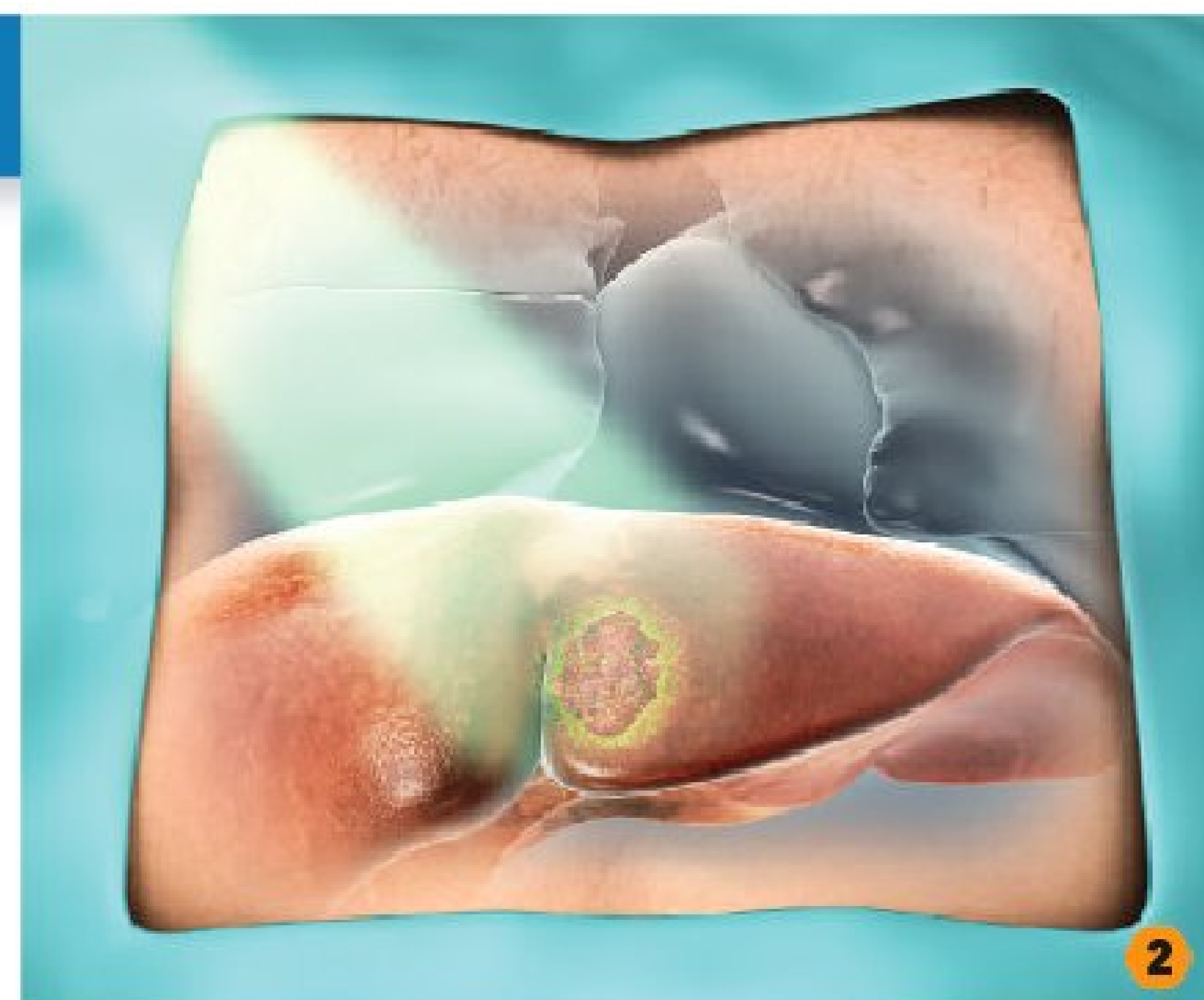
Fluorescent imaging helps surgeons cut more cancer cells

There's too much guesswork in cancer surgery. Although a tumor is usually a different color or density than the healthy tissue around it, stray cancer cells near the tumor often blend in, so surgeons carve out an extra fraction of an inch surrounding it. But if post-op tests prove that the extracted tissue has cancer cells on its edge, another round of surgery is required. This happens frequently: About 20 percent of breast-cancer patients need a second surgery because of lingering cancer cells.

With their new imaging system, scientists at GE might have found

a fix. Before surgery, doctors using GE's system would inject into the patient's vein a fluorescent dye solution that seeks out dangerous cells surrounding the tumor. Surgeons would illuminate the tagged cells with infrared light, creating a glowing halo. A real-time image of the tagged cells is then overlaid on a video of the patient's anatomy. Kathleen Bove of GE's biomedical imaging lab says that in tests on rats, the imaging system helped scientists remove peripheral cancer cells, lessening the need for follow-up surgeries.

—AMANDA SCHUPAK



Doctors inject a fluorescent dye [1], which under infrared light illuminates the cells surrounding a tumor [2], helping surgeons remove more of the cancer [3].

ILLUSTRATION: MEDI-MATION; PHOTOGRAPHS: SHEEP: ISTOCK; TNT: GETTY IMAGES

**IMPRESSIVELY ANNOYING** A 23-year-old Russian hacker was arrested for using a network of more than 500,000 zombie computers to send 10 billion spam e-mails in a day.



# gravity defyer™

VERSOSHOCK TRAMPOLINE FOOTWEAR

## Scientifically Engineered to Defy Gravity

# Defy Pain, Defy Aging, Defy Fatigue

### This is my story

I used to be more active. I used to run, play basketball, tennis, football... I was more than a weekend warrior. I woke up every day filled with life! But now, in my late 30's, I spend most of my day in the office or sacked out in front of the TV. I rarely get to the gym – not that I don't like working out, it's the nagging pain in my knees and ankles. Low energy and laziness has

got me down. My energy has fizzled and I'm embarrassed to admit that I've grown a spare

tire (I'm sure it's hurting my love life). Nowadays I rarely walk. For some reason it's just harder now. Gravity has done a job on me.

### Customer Satisfaction Speaks for Itself!

4 out of 5 customers purchase a 2nd pair within 3 months.

### Wear them and you'll know

That's what my doctor recommended. He said, "Gravity Defyer shoes are pain-relieving shoes." He promised they would change my life—like they were a fountain of youth. "They ease the force of gravity, relieving stress on your heels, ankles, knees and back. They boost your energy by propelling you forward." The longer

he talked, the more sense it made. He was even wearing a pair himself!

### Excitement swept through my body like a drug

I received my package from GravityDefyer.com and rushed to tear it open like a kid at Christmas. Inside I found the most amazing shoes I had ever seen – different than most running shoes. Sturdy construction. Cool colors. Nice lines... I was holding a miracle of technology. This was the real thing.

### GDefy Benefits

- Relieve pain
- Ease joint & spinal pressure
- Reduce fatigue & tiredness
- Be more active
- Have more energy
- Appear taller
- Jump higher, walk and run faster
- Have instant comfort
- Cool your feet & reduce foot odor
- Elevate your performance

I put them on and all I could say was, "WOW!" In minutes I was out the door. I was invincible; tireless in my new Gravity Defyer shoes. It was as if my legs had been replaced with super-powered bionics. What the doctor promised was all correct. No more knee pain. I started to lose weight. At last, I was pain free and filled with energy! I was back in the game. Gravity had no power over me!



**ABSORB SHOCK**  
Eliminate pain from every step.

### Nothing to lose: 30 Day Free Trial\*

So, my friend, get back on your feet like I did. Try Gravity Defyer for yourself. You have nothing to lose but your pain.



**REBOUND PROPELS YOU FORWARD**  
Reduce fatigue. Be more active.

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VersoShock™ Trampoline Shock-Absorbing Membrane Heel

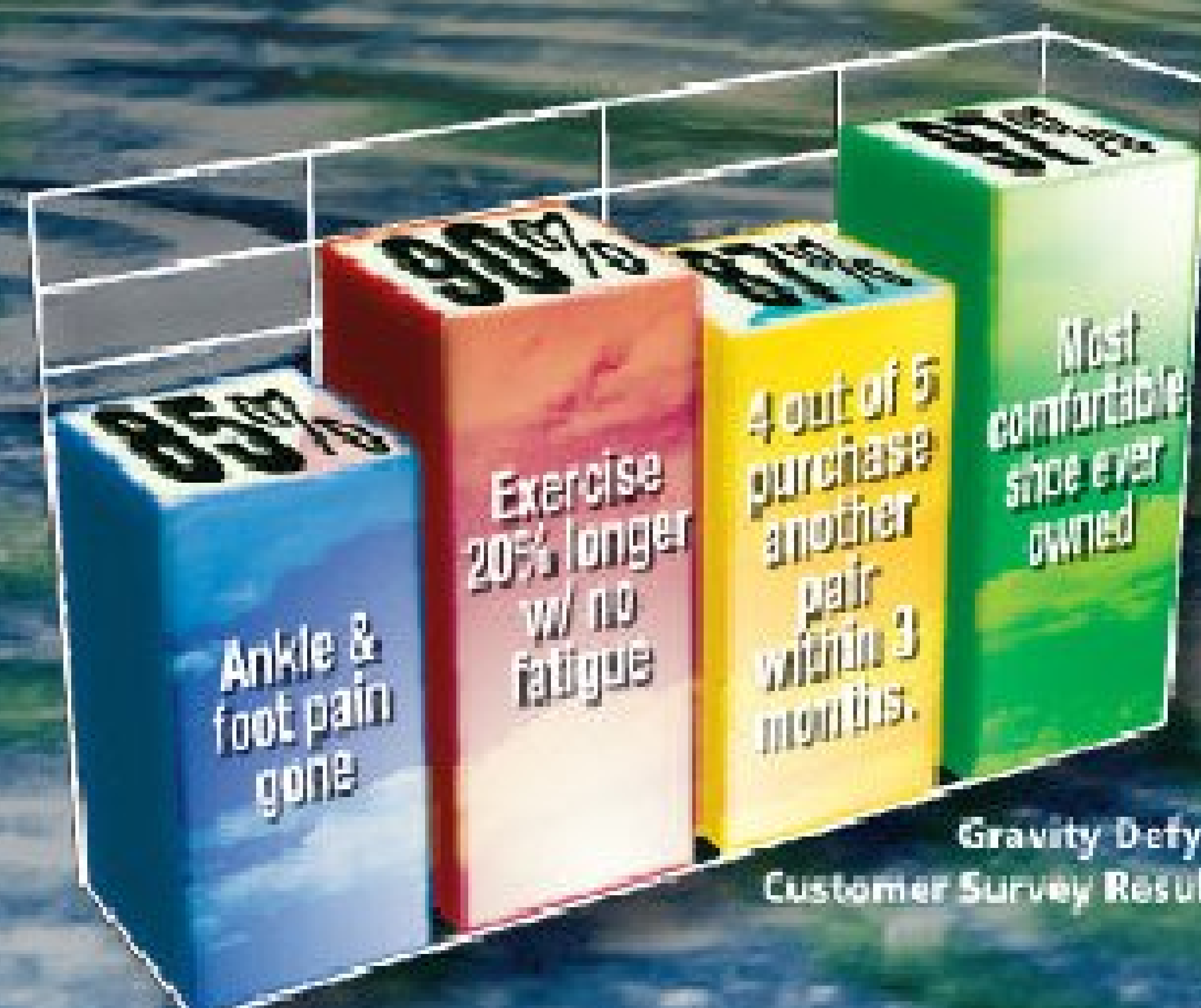
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Resilient High Grade Ethylene-Vinyl Acetate (EVA) Midsole  
Rocker construction protects metatarsal bones and aids fluid stepping motions

Rugged Polymer Sole



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Med/Wide and ExtraWide/XXWide Widths  
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TB902FBL  
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## HEADLINES ANNOTATED MACHINE

# BODY SNATCHER, LIFESAVER

A robo-sub helps rescue drowning victims in minutes

Things get very bad, very quickly, for people in cold water. Just minutes after total submersion, heart and brain activity stop. But the cold also protects. If rescuers can reach a drowning victim in less than 90 minutes, it's possible to resuscitate, often with no long-term ill effects. Inspired by this fact, Duncan Winsbury, a former station manager at the Fire & Rescue Service in Derbyshire, England, set out to build a robot that could find and retrieve cold-water drowning victims fast.

### WATERY GRAVES

When an unconscious body sinks below 15 feet, water pressure can hold it down forever. The SARbot could discover human remains that have long been missing.

Winsbury explained his vision to Jesse Rodocker, the co-founder of Seattle robot-maker SeaBotix, and the duo made SARbot, upgrading a shoebox-size remotely operated sub typically used to salvage shipwrecks. The robot transmits sonar and video data to land via a cable. Rescuers then can use its arm to latch onto a victim and haul both him and the 'bot in like a lobster trap.

SARbot is simple enough that trained rescuers can get it in the water in four minutes. In tests last

year, it found practice dummies less than five minutes after hitting the water. "Only a few fire departments carried the jaws of life when it debuted," Rodocker says. "Now they're on nearly every truck. SARbot could have a similar impact."

Impressed by SARbot's performance, U.K. officials have shown interest in purchasing a fleet, as have officials in Seattle and Chicago. "This can help cut drowning deaths in half," Winsbury says. "And we never have to get our feet wet."—BJORN CAREY



### ▲ SONAR SCAN

Wide-angle 720-kilohertz sonar with a 120-foot range scans the seabed for anomalous objects. In a future version, it will overlay scans on a 3-D map.

### SURE HANDS

Large robotic arms and hands can secure themselves around a person's arm or leg or securely hold onto clothing.

### LIFELINE (Not Shown)

Data cables and a power cord are all packed into a 0.3-inch tether, thin enough that it's neutrally buoyant and minimizes drag. The tether also has a tensile strength greater than 500 pounds, so it won't snap as rescuers pull up a body.

### WATER VISION

A high-resolution, low-light camera with LED lighting makes it possible to see a body from up to 30 feet away. Underwater, brown colors dominate, so a video enhancer strips out the dirt and brings out prominent reds and greens to highlight bodies.

### STRONG SWIMMER

SARbot's thrusters propel the robot at about 3 knots, allowing it to work in the currents of most rivers and tidal areas.

COURTESY SEABOTIX

**STRETCH SUPERCAR** The six-wheeled, nearly 14-foot-long Italian sports car Covini C6W was unveiled after 32 years in development.





❖ **Gout's root cause is high uric acid.** If you have gout, high uric acid can lead to more attacks. To help reduce attacks, lower your uric acid.

**ULORIC can help.** ULORIC is clinically proven to help lower uric acid to a healthy level (less than 6 mg/dL).

**Struggling with gout?** Ask your doctor how ULORIC can help lower uric acid and bring gout's root cause down to a more manageable size.

### Use of ULORIC

ULORIC is a prescription medicine used to lower blood uric acid levels in adults with gout. ULORIC is not for the treatment of high uric acid without a history of gout. Individual results may vary.

### Important Safety Information

- Do not take ULORIC if you are taking Azathioprine, Mercaptopurine, or Theophylline.
- Your gout may flare up when you start taking ULORIC; do not stop taking your ULORIC even if you have a flare. Your healthcare provider may give you other medicines to help prevent your gout flares.
- A small number of heart attacks, strokes, and heart-related deaths were seen in clinical studies. It is not certain that ULORIC caused these events.
- Tell your healthcare professional about liver or kidney problems or a history of heart disease or stroke.

- Your healthcare professional may do blood tests to check your liver function while you are taking ULORIC.
- The most common side effects of ULORIC are liver problems, nausea, gout flares, joint pain, and rash.

Please see accompanying Important Patient Information for ULORIC on adjacent page and talk to your healthcare professional.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit [www.fda.gov/medwatch](http://www.fda.gov/medwatch), or call 1-800-FDA-1088.

For more information, visit [www.ULORIC.com](http://www.ULORIC.com) or call 1-877-ULORIC-6.



Learn more

Use ScanLife or text GOUT to 299669. You can also download a QR-Code Reader at [www.2dscan.com](http://www.2dscan.com).

Message and data rates may apply. May not be available on all devices.



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**Uloric**  
(febuxostat) 40 mg/80 mg  
tablets



# PATIENT INFORMATION

## ULORIC® (Ū-'lor-ik) (febuxostat) tablets



Read the Patient Information that comes with ULORIC before you start taking it and each time you get a refill. There may be new information. This information does not take the place of talking with your healthcare provider about your medical condition or your treatment.

### WHAT IS ULORIC?

ULORIC is a prescription medicine called a xanthine oxidase (XO) inhibitor, used to lower blood uric acid levels in adults with gout.

It is not known if ULORIC is safe and effective in children under 18 years of age.

### WHO SHOULD NOT TAKE ULORIC?

**Do not take ULORIC if you:**

- take Azathioprine (Azasan®, Imuran®)
- take Mercaptopurine (Purinethol®)
- take Theophylline (Theo-24®, Elixophyllin®, Theochron®, Theolair®, Uniphyll®)

It is not known if ULORIC is safe and effective in children under 18 years of age.

### WHAT SHOULD I TELL MY HEALTHCARE PROVIDER BEFORE TAKING ULORIC?

Before taking ULORIC tell your healthcare provider about all of your medical conditions, including if you:

- have liver or kidney problems
- have a history of heart disease or stroke
- are pregnant or plan to become pregnant. It is not known if ULORIC will harm your unborn baby. Talk with your healthcare provider if you are pregnant or plan to become pregnant.
- are breast-feeding or plan to breast-feed. It is not known if ULORIC passes into your breast milk. You and your healthcare provider should decide if you should take ULORIC while breast-feeding.

Tell your healthcare provider about all the medicines you take, including prescription and non-prescription medicines, vitamins, and herbal supplements. ULORIC may affect the way other medicines work, and other medicines may affect how ULORIC works.

Know the medicines you take. Keep a list of them and show it to your healthcare provider and pharmacist when you get a new medicine.

### HOW SHOULD I TAKE ULORIC?

- Take ULORIC exactly as your healthcare provider tells you to take it.
- ULORIC can be taken with or without food.
- ULORIC can be taken with antacids.
- Your gout may flare up when you start taking ULORIC, do not stop taking your ULORIC even if you have a flare. Your healthcare provider may give you other medicines to help prevent your gout flares.
- Your healthcare provider may do certain tests while you take ULORIC.

### WHAT ARE THE POSSIBLE SIDE EFFECTS OF ULORIC?

Heart problems. A small number of heart attacks, strokes and heart-related deaths were seen in clinical studies. It is not certain that ULORIC caused these events.

The most common side effects of ULORIC include:

- liver problems
- nausea
- gout flares
- joint pain
- rash

Tell your healthcare provider if you have any side effect that bothers you or that does not go away. These are not all of the possible side effects of ULORIC. For more information, ask your healthcare provider or pharmacist.

Call your doctor for medical advice about side effects. You may report side effects to the FDA at 1-800-FDA-1088.

### HOW SHOULD I STORE ULORIC?

Store ULORIC between 59°F - 86°F (15°C - 30°C).

Keep ULORIC out of the light.

Keep ULORIC and all medicines out of the reach of children.

### GENERAL INFORMATION ABOUT THE SAFE AND EFFECTIVE USE OF ULORIC.

Medicines are sometimes prescribed for purposes other than those listed in a patient information leaflet. Do not use ULORIC for a condition for which it was not prescribed. Do not give ULORIC to other people, even if they have the same symptoms that you have. It may harm them.

This patient information leaflet summarizes the most important information about ULORIC. If you would like more information about ULORIC talk with your healthcare provider. You can ask your healthcare provider or pharmacist for information about ULORIC that is written for health professionals. For more information go to [www.uloric.com](http://www.uloric.com), or call 1-877-825-3327.

### WHAT ARE THE INGREDIENTS IN ULORIC?

**Active Ingredient:** febuxostat

**Inactive ingredients include:** lactose monohydrate, micro-crystalline cellulose, hydroxypropyl cellulose, sodium croscarmellose, silicon dioxide, magnesium stearate, and Opadry II, green



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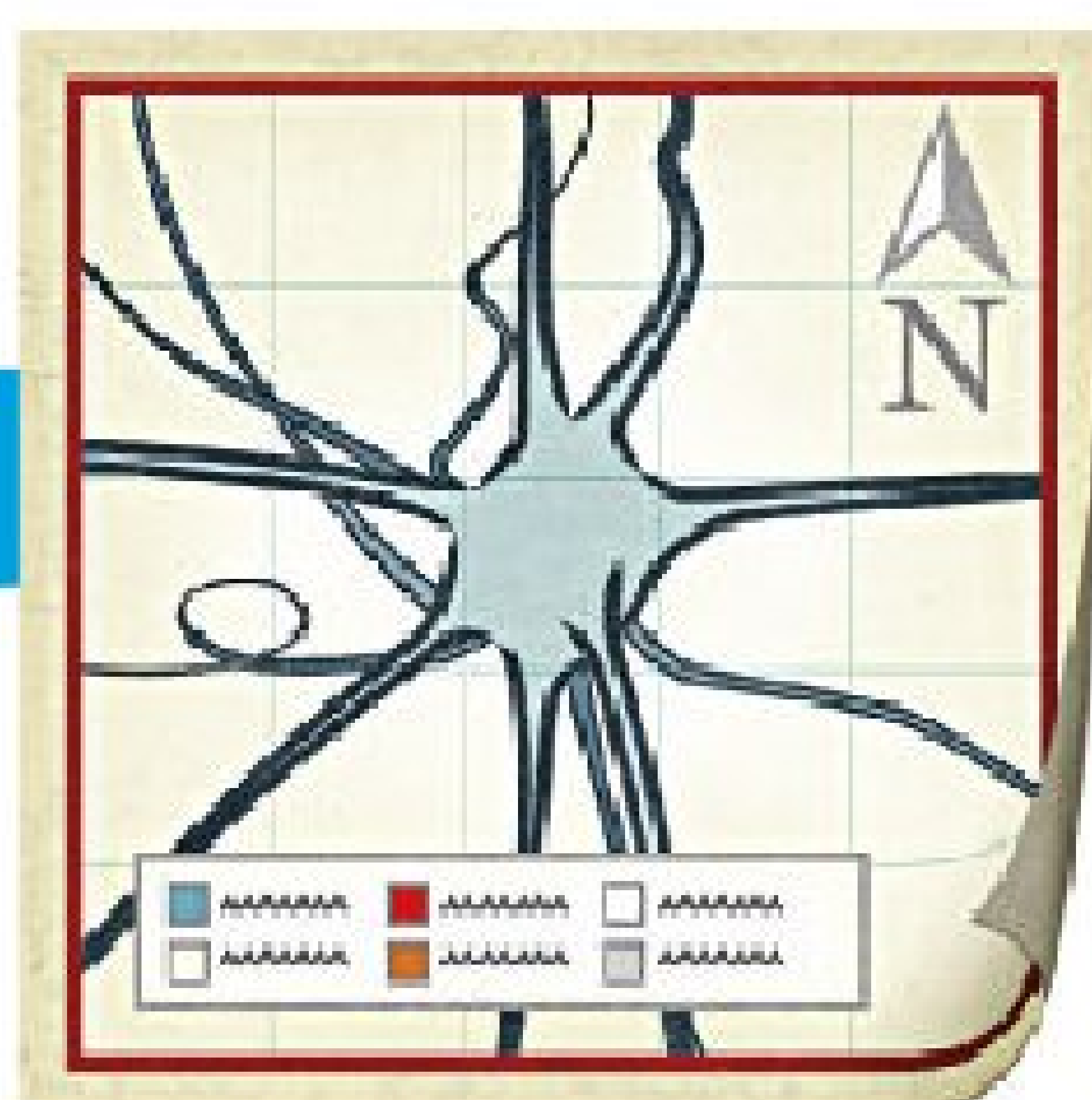
# BRAIN POWER

Building computers that work like a mind

**The most efficient computer** in the known universe is a three-pound blob with no user's manual: the human brain, which in a day's work requires no more fuel than the caloric energy in a BLT. In contrast, IBM's Dawn supercomputer, which used 147,456 850-megahertz processors to run a simple simulation on the

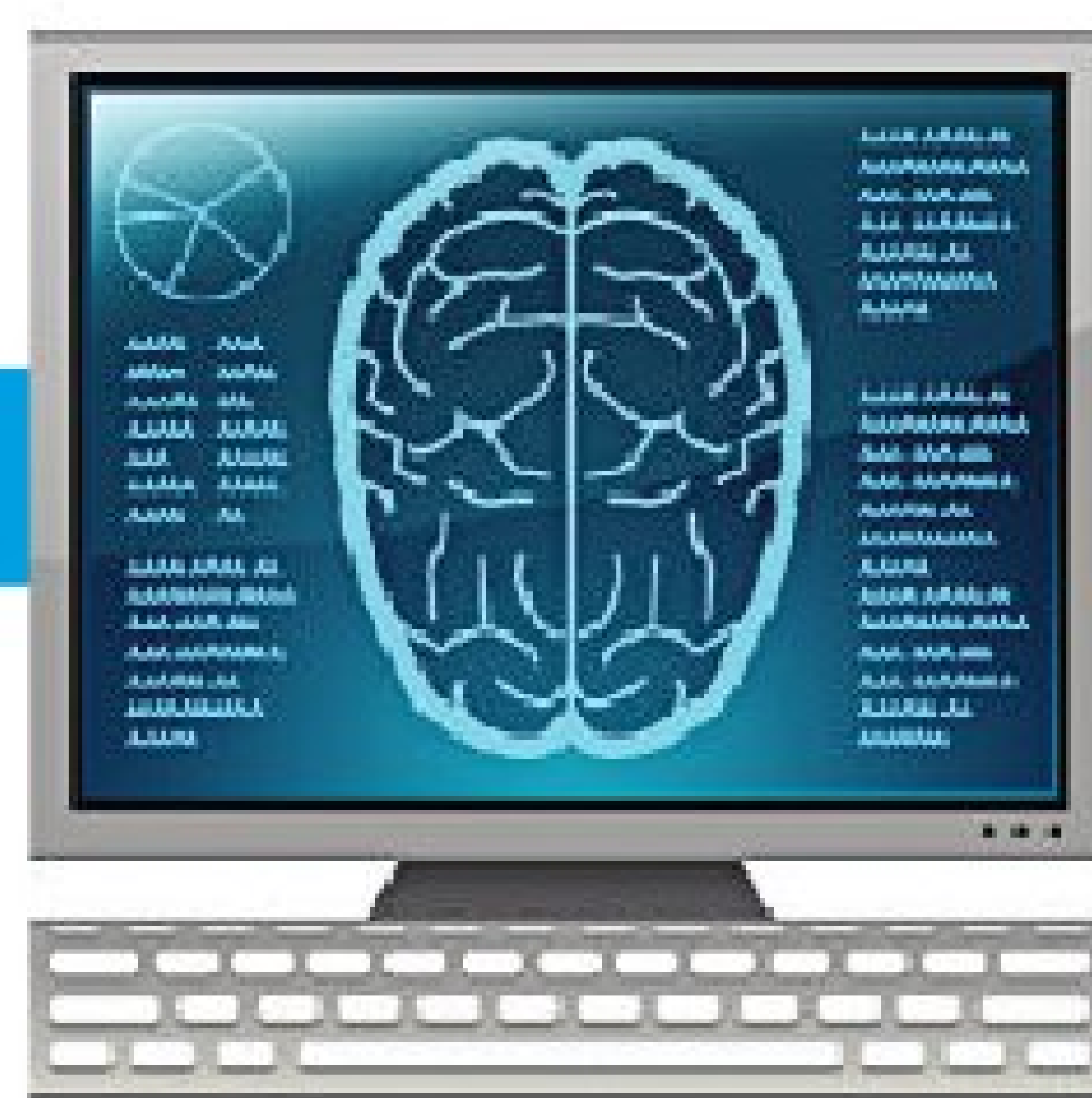
scale of a cat's cortex, requires the equivalent of roughly 50,000 BLTs every 24 hours.

Unsurprisingly, neuroscientists and computer engineers are hard at work attempting to duplicate the fast-acting, power-saving mechanics of our brain. To even approach computer performance on that scale, however, scientists need a better blueprint of the network of neurons beneath our skull, richer software models of how it works, and sophisticated hardware to run the simulations. Here are three projects that could come together to build a brilliant robotic brain.—ANDREW ROSENBLUM



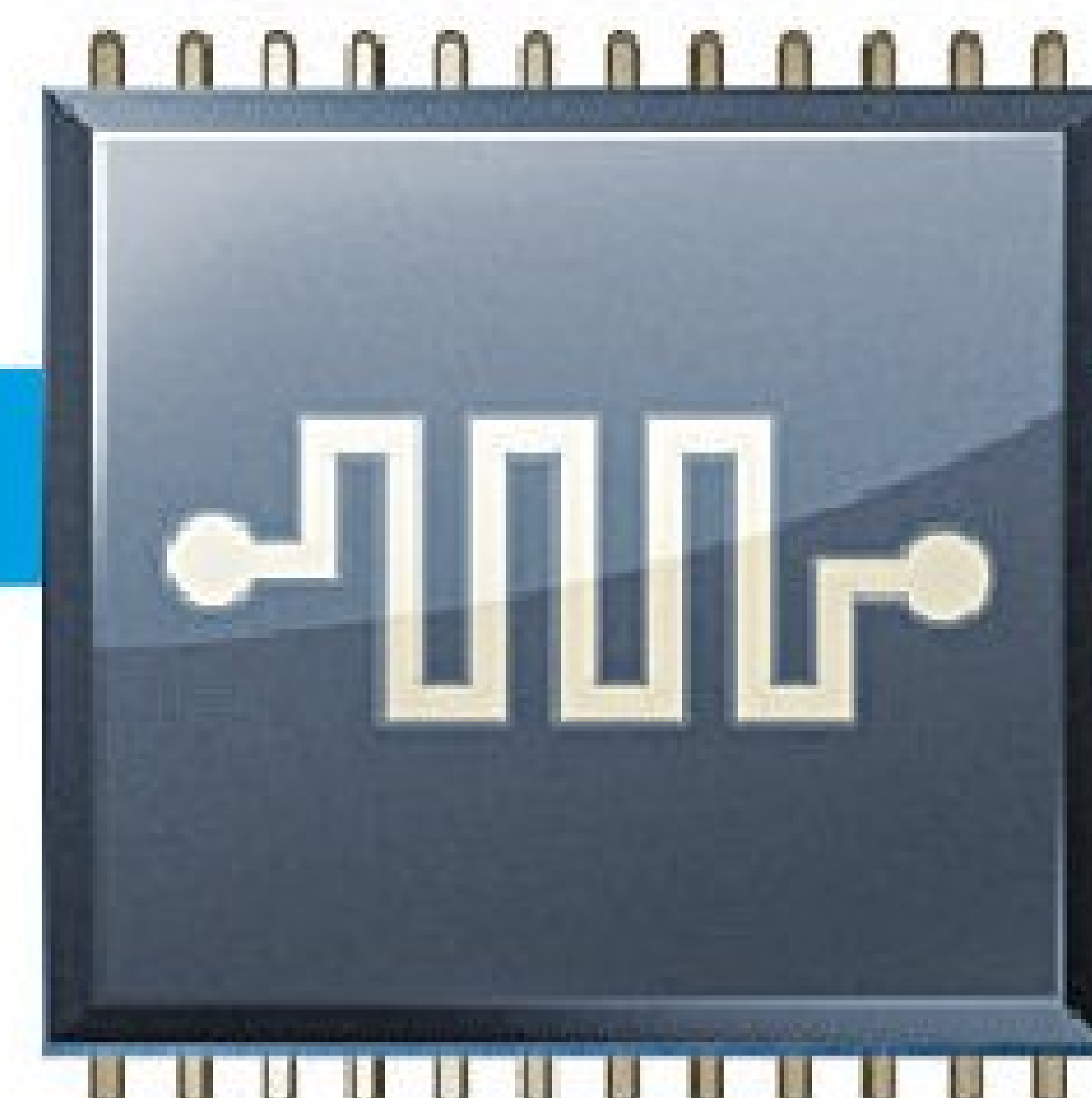
## CONNECTOME

Figure out how 100 billion neurons communicate



## BLUE GENE

Create software that models the brain



## DARPA SYNAPSE

Design energy-efficient hardware powerful enough to run software inspired by the brain

CHALLENGE

SOLUTION

MILESTONES

BENEFITS

Some researchers are painstakingly tracing synapses by hand—each neuron takes 10 people an hour, so mapping trillions of synapses one by one could take millennia. Instead, the Human Connectome Project involves teams of researchers using imaging techniques like MRI scans to map how parts of the brain connect with each other on a larger scale.

By modeling every little pulse of the electrical activity of small groups of neurons, Henry Markram of the École Polytechnique Fédérale de Lausanne in Switzerland is creating software models of how they communicate. He aims to scale up to a software model of the entire human brain within 10 years.

HP, funded by Darpa, the Pentagon's R&D branch, is working to build chips incorporating the "memristor," a resistor with memory. Like a synapse, a memristor can remember how its connected "neurons" have fired in the past. Because of its nanoscale size, the memristor combines high computation density with low energy needs.

Teams from the University of Minnesota and Washington University will use ultra-high-magnetic-field MRI to map connections between brain areas in 1,200 healthy adults by 2014.

Markram says he is close to simulating one million neurons and that a previous, smaller-scale 3-D digital model has shown responses to stimuli in ways similar to those of a real rat brain.

Next month, collaborators at Boston University aim to have an intelligent system using memristors that can perform functions like perception, navigation and decision-making.

These studies will help build more-accurate anatomical models of brain functions like memory and provide healthy models against which to compare patients who have mental disorders such as autism and Alzheimer's.

Detailed neuron simulations would be a boon to companies working on synthetic neurotransmitters and other mood-altering drugs, potentially making animal testing unnecessary.

Shuffling information between processors and memory has been a bottleneck in computer design. Having part of the chip handle both tasks could increase processing power and energy efficiency.

**CSI-ESQUE** A new forensics method finds a suspect's age to within nine years from a blood sample. The test analyzes immune cells' DNA, which changes over time.



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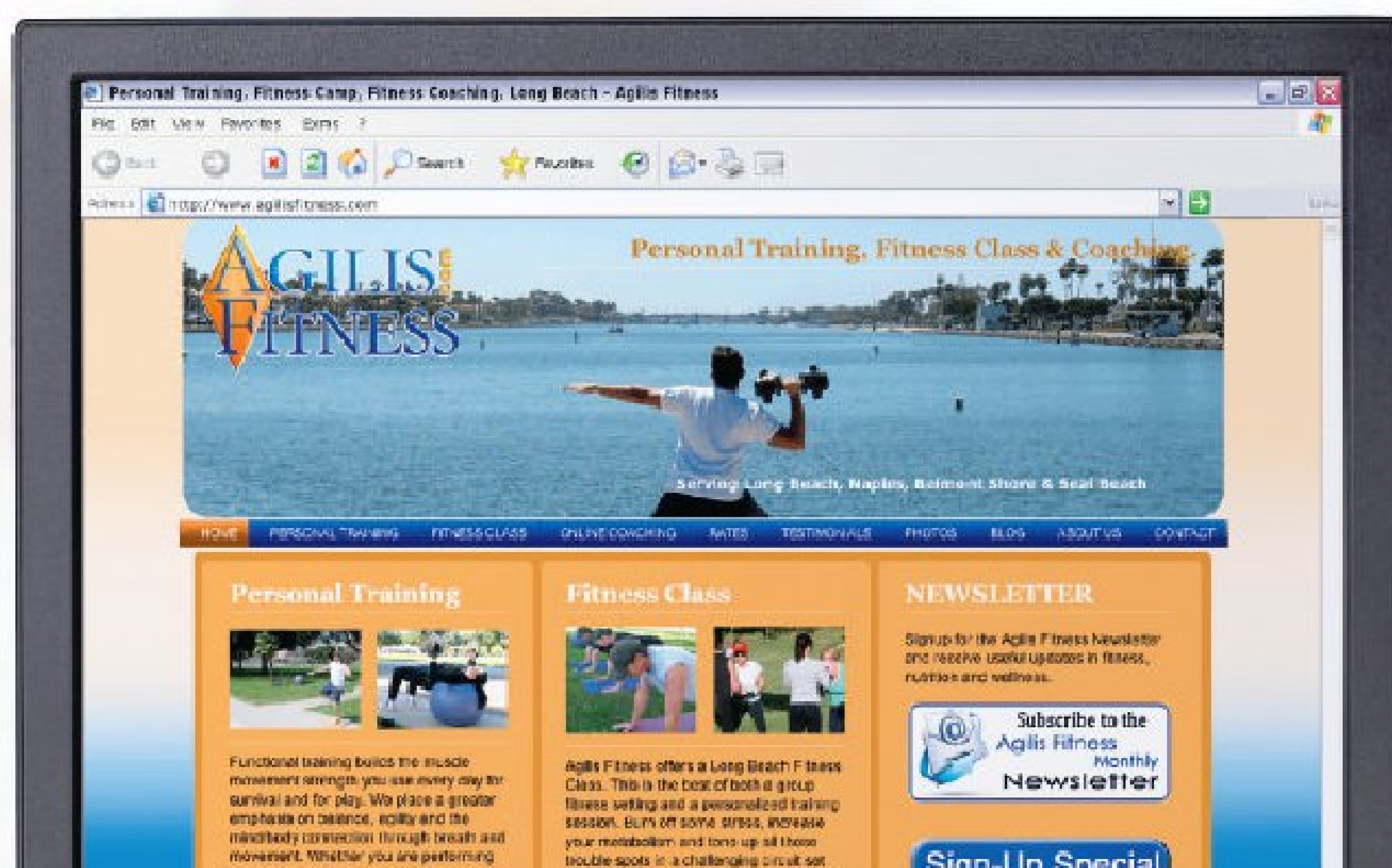
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# 1 FLYING HUMMERS

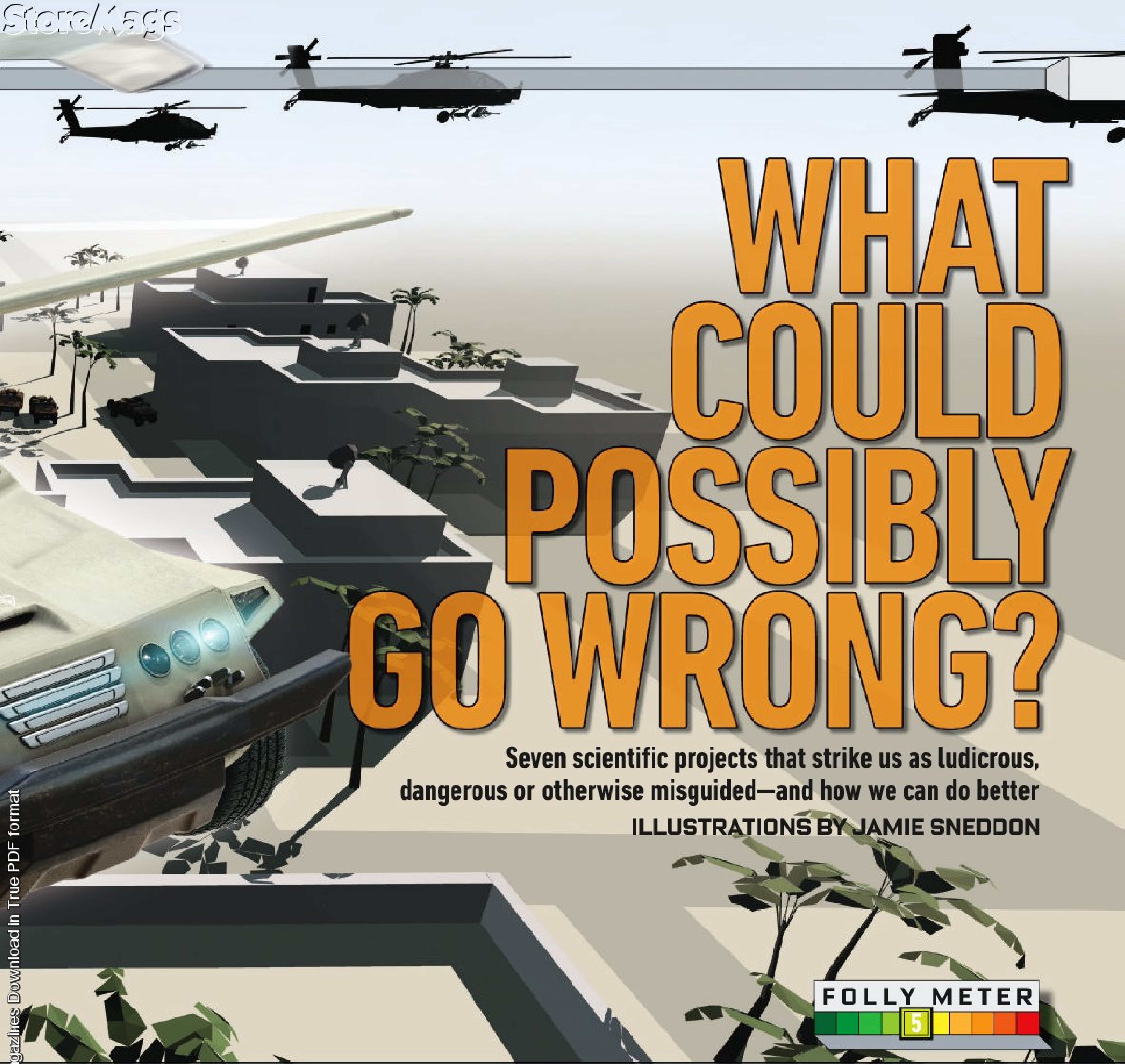
Last April, Darpa proposed a novel solution to the problem of IED-strewn roads and otherwise impassable landscapes in Afghanistan and elsewhere: fly over them. The Pentagon agency's \$50-million-plus exploratory program for the Transformer (TX) calls for a "robust ground vehicle" that can quickly transform into a vertical-takeoff-and-landing (VTOL) aircraft with a 1,000-pound payload capacity and a flying range of nearly 300 miles. Darpa has a daunting

list of specs for any would-be contractors: It must be able to take on small-arms fire and meet federal standards for safety and crash protection. It's got to have four-wheel drive and be able to reach an altitude of 10,000 feet. Oh, and should the driver become incapacitated, it has to be able to fly itself.

It's a lot to ask. The fundamental challenge of making cars fly is combining two distinct sets of optimal design characteristics into one package without sacrificing

too much performance on either end. The very phrase "roadable air vehicle" sounds like a sigh of compromise. The military considered developing a hybrid in the 1950s with the ungainly Piasecki PA-59K, or "AirGeep," but then abandoned it because of cutbacks in military research. Advances in materials science and propulsion technology have lessened the trade-offs, but many challenges remain. First, weight. NASA engineer Mark Moore says that, as a rule, conventional





# WHAT COULD POSSIBLY GO WRONG?

Seven scientific projects that strike us as ludicrous, dangerous or otherwise misguided—and how we can do better

ILLUSTRATIONS BY JAMIE SNEDDON

## FOLLY METER

5

aircraft grow roughly three pounds heavier for every extra pound of payload they're supposed to carry, whereas, "VTOL aircraft grow about five to six pounds heavier for every extra pound of weight." Now picture a VTOL aircraft that happens to be armored and packing four soldiers and their equipment. The required compact, rotorless propulsion system means, Moore says, a "hurricane-speed flow field" of rocks and debris upon takeoff. So much for stealth. And all of this likely

would do little to increase security. Transformers may be able to leap over IEDs, but insurgents can simply aim RPGs at the wings, which on one proposed Transformer design are laden with fuel tanks. Enemy combatants in Iraq have brought down Blackhawk helicopters, which are faster and more maneuverable, with small-arms fire. As for the autopilot function—nearly half of the finalists in Darpa's 2007 Urban Challenge for autonomous ground vehicles were unable to

▲ **SUICIDE RIDE**  
A flying Hummer would be inherently unstable and vulnerable to small-arms fire.

execute elemental driving tasks. There is little reason to believe that autopiloting an inherently unstable vehicle through a battle space under hostile conditions will work better.

### HOW WE CAN DO BETTER

Stay focused on making actual Hummers tougher and more versatile. "We still don't have a fighting vehicle capable of negotiating rough terrain," says retired Major General Robert Scales, a military analyst.—TOM VANDERBILT



## 2 BLOTTING OUT THE SUN

Engineering the atmosphere to forestall the worst results of global warming was once considered too hubristic to seriously contemplate. The grim prospects for passing an international climate-change treaty have changed that. Last year the National Academies of Science in the U.S. and the Royal Society in the U.K. both convened meetings on geoengineering. The schemes generally fall into two categories—CO<sub>2</sub> capture (pulling carbon dioxide from the air) or solar-radiation management (reflecting sunlight)—but it's a form of the latter, which involves using airplanes or long hoses to pour sulfate aerosols into the lower stratosphere, that's the most audacious. Once in the stratosphere, the theory goes, the aerosols would reflect some solar radiation and prevent a devastating rise in the average global temperature. The theory is not crazy. In 1991, after the eruption of Mt. Pinatubo in the Philippines spewed 20 million tons of sulfur dioxide into the stratosphere, the average global temperature dropped by about 1°F from 1991 to 1993. But administering such a program well would require an unprecedented degree of international coordination and funding, and the odds of miscalculation are high.

And the potential negative consequences are, in the worst case, extreme. Consider a hypothetical scenario in the year 2030. Severe

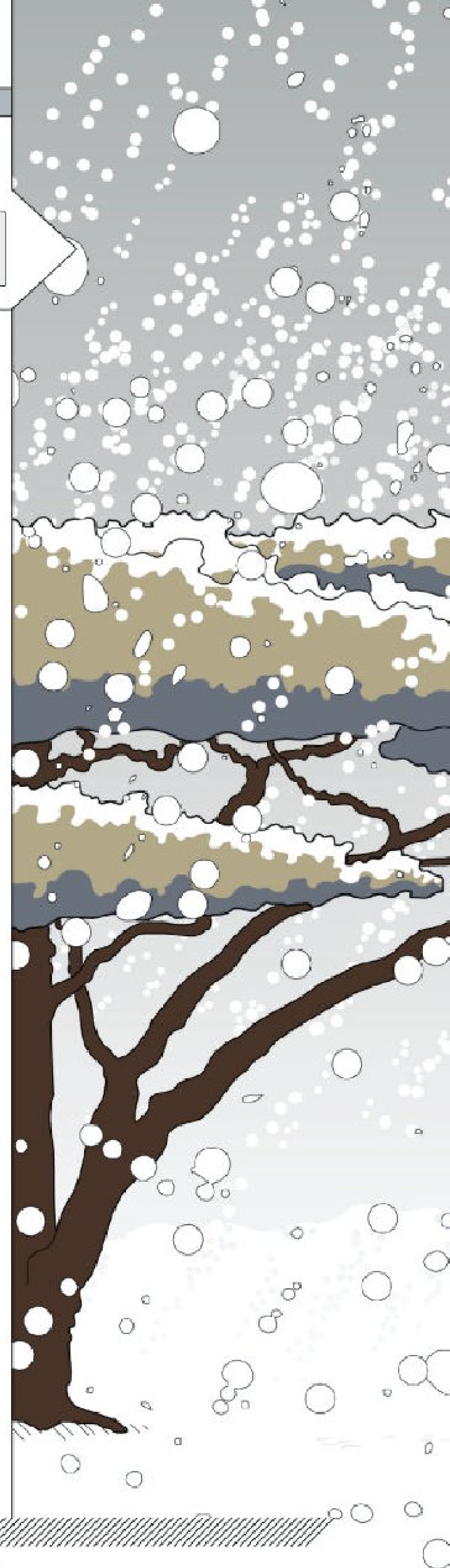
► **SUN SHADE**  
Filling the stratosphere with sulfur aerosols could cool the globe, but it could also cause widespread drought and destruction.

storms and floods, prolonged droughts and wildfires have become commonplace. China has become the world's largest economy, and two decades of coal-fired hyper-growth have overwhelmed the country's advances in clean energy and efficiency. It is losing nearly 2,000 square miles a year to desertification, at a cost of \$10 billion annually. Its eastern agricultural regions, which once fed a substantial fraction of the world's population, have seen water tables decline precipitously from drought and overuse. Food shortages have become widespread.

Under pressure to address climate change yet unable to slow growth without risking domestic unrest, the Chinese government pressures the U.S. and the European Union to cooperate on a program of geoengineering. It proposes launching military aircraft into the lower stratosphere to release several million tons a year of sulfur-based gases, with the intent of reflecting sunlight and blunting the rise in global temperature. The U.S. and E.U. balk, and China goes ahead alone. Lacking the power to stop it, Western countries look on in dismay as Chinese jets take to the sky.

The U.S. soon has no choice but to step in as a partner, if only to stabilize the delivery and geographic dispersal of the particles. With the world's two most powerful nations now perceived as "in charge" of the

# GEOENGINEERING COULD CAUSE MORE PROBLEMS THAN GLOBAL WARMING ITSELF







FOLLY METER



climate, other countries suspect that they are manipulating the weather to their own benefit. Every flood or fire is seen as a Sino-American responsibility.

After about five years, scientists begin to realize that blocking sunlight causes far worse side effects than anticipated. Less heat has meant less evaporation and less water entering the hydrological cycle. The Asian and African monsoons bring less and less rain, leading to droughts that disrupt food supplies for billions of people. Meanwhile ocean acidification, which sun-blocking does not mitigate, has begun to shut down major fisheries.

After 10 years, pressure from battered countries is overwhelming. To avert war, China and the West abandon their geoengineering programs, despite the frantic protests of their scientists. And what happens next is even worse.

Within two years, atmospheric sulfur levels plunge to pre-geoengineering levels, and the global average temperature, artificially suppressed for a decade, comes roaring back. Once again, patterns of precipitation and temperature shift abruptly, wiping out the efforts of the world's farmers to adapt to the changes of the decade prior. The high temperatures free billions of tons of methane—a greenhouse gas 30 times as potent as  $\text{CO}_2$ —from the melting Arctic permafrost, which in turn accelerates warming. The process becomes self-reinforcing and unstoppable. By 2050, starvation, disease and near-constant armed conflict have devastated the developing world. India and Pakistan, starving, desperate and paranoid, are on a nuclear hair trigger. Then a bomb goes off in India, and things really start going badly.

### HOW WE CAN DO BETTER

Avoid having to even contemplate geoengineering by keeping atmospheric  $\text{CO}_2$  levels low—ideally, to 350 ppm—DAVID ROBERTS





## INDUSTRIAL CYBER-SABOTAGE



Computers already do so much of our work that it seems natural to let them take care of our sabotage, too.

This might have been the line of thinking that led to Stuxnet. The first known malware worm designed to disrupt industrial processes, Stuxnet began spreading in early 2009. It's unclear who wrote the worm, or why, but a consensus is gathering that a government (probably Israel's) created the worm to sabotage the Iranian nuclear program. Stuxnet seeks out and silently hijacks factory control software written by Siemens. Once it infects the computers running that software, it can command uranium-enriching centrifuges to spin out of control, thereby destroying them. Computers such as these are kept disconnected from the Internet, so getting Stuxnet to its target probably required someone to load the worm onto a USB stick used by a plant employee or contractor. Once that person plugged his USB stick in at work, Stuxnet probably began crawling through the plant's local-area network, searching for the right computer to hijack. Exactly how much damage it did, we don't know, but the Iranian nuclear program did

▲ **EPIC FAIL**  
**Malicious programs could blow up factories and sabotage power grids.**

appear to slow, and last November Iranian president Mahmoud Ahmadinejad confirmed that a malicious computer program caused "problems" with centrifuges.

But somehow Stuxnet also made it to the Internet, and by last fall, the worm had infected hundreds of thousands of computers in at least 155 countries. Siemens says that to date, only 15 *industrial* facilities worldwide have been infected. So far, nothing has happened that we know of, but the potential for mischief is still high. The operating system that Stuxnet is designed to hijack controls pipelines, conveyor belts, boilers, alarm systems and access controls, among other things,

and experts warn that it and similar worms could, in theory, blow up factory boilers, destroy gas pipelines, sabotage power plants, and disrupt power grids. Now that Stuxnet has given hackers a sophisticated blueprint for creating such worms, many cybersecurity wonks are thoroughly freaked out.

### HOW WE CAN DO BETTER

Cybersecurity consultant Stephen Spoonamore says that we should immediately redesign all critical infrastructure to "fail open," meaning that in the event of a cyber attack, the system will default to a basic operating mode and keep running.—BECKY FERREIRA

# STUXNET GIVES HACKERS A BLUEPRINT FOR SOPHISTICATED NEW MALWARE.



4

## DEEP-DRILLING A SUPERVOLCANO

When **Mt. Vesuvius** erupted in A.D. 79, the people around it had little warning, and more than 10,000 of them died as a result. Bad as that was, an eruption of neighboring Campi Flegrei could be worse. As a supervolcano, it's in the same category as Indonesia's Mt. Tambora, whose eruption in 1815 killed 92,000 people and caused the "year without a summer." Campi Flegrei's eight-mile-wide caldera is so low and unassuming that much of metro Naples was built on top, and yet a full eruption would be one of the largest in human history, the kind of geological event capable of plunging the world into a minor ice age. This time, scientists are determined to give the three million residents of greater Naples abundant warning.

That's part of the motivation behind the Campi Flegrei Deep Drilling Project. Co-sponsored by the European Union, a coalition of scientists from 18 countries plans to drill deep into the volcano and implant sensors that will measure changes in temperature, the movement of magma, and seismic activity. The first phase of the project involves drilling a 1,640-foot borehole to study the composition of the rock; phase two, drilling the narrow 2.4-mile master hole. Data collected from sensors that the scientists place at the bottom of those holes will make it possible to map the volcano's underground geometry with unprecedented precision. It could also give local authorities early warning if an eruption becomes imminent.

Either that, or the drilling itself could cause a disaster. "There's going to be seismic activity," says Robert J. Bodnar, a geochemistry professor at

▲ **FIRE BOMB**  
There are few good ways to deal with living atop a supervolcano, but critics worry that drilling deep into one to study its composition could, in the worst case, cause an earthquake or eruption.

FOLLY METER

3



Virginia Tech who has studied the site for 10 years. What's unclear is how much of a problem that would be. Bodnar says that any drilling-induced activity would be so minor that it would be felt only by seismometers, but he admits that it's impossible to rule out more severe consequences. If the drill hit an unexpected hydrothermal pocket it could cause explosions. Noxious gases such as hydrogen sulfide could also escape, possibly causing explosions as they escape and even triggering seismic activity. Or the gases could poison the topsoil. The worst-case scenario, however unlikely, is that a shock to the Campi Flegrei system would set off a chain reaction that ended in an earthquake or even a full-on volcanic eruption. Similar disasters have happened before: In 2006, a scientific drilling project on the Lusi volcano in Indonesia triggered an eruption that killed 13 people and displaced 30,000. Scientists on the project argue that the hole they're drilling is too small to be dangerous. But at press time, the project was on hold. As the mayor of Naples, Rosa Russo Iervolino, told *Newsweek* last fall, without a guarantee that the project is safe, "there will be no drilling in any part of the caldera."

#### HOW WE CAN DO BETTER

Monitor the volcano's seismic activity from the surface, and develop a rapidly executable plan for moving Naples's citizens to safety.—KARLA STARR



## GENETICALLY MODIFIED

**As carriers for diseases** such as malaria, dengue fever and yellow fever, mosquitoes are the deadliest creatures on the planet, responsible for millions of human deaths every year. And as the planet warms, the insects are broadly expanding their turf and bringing their diseases with them; thousands of cases of dengue, a tropical disease, have appeared in the U.S. in the past five years. DDT was long used to control the mosquito population, but it is now widely banned, and in any case, many scientists believe that mosquitoes quickly build up a resistance to the insecticide. That, in part, is why the battle against mosquitoes has gone genetic.

Generally speaking, the goal of gene-based mosquito-control projects is either to kill the insects or make them benign. Researchers at Johns Hopkins University, for example, are studying mosquitoes that were made malaria-resistant through the activation of a gene responsible for a protein that blocks the infection. And the British company Oxitec has engineered a strain of mosquito that cannot survive without regular doses of tetracycline; in the wild, these mosquitoes would survive just long enough to mate and pass on their tetracycline-junkie genes to their doomed offspring. In a trial in the Cayman Islands last year, Oxitec-modified mosquitoes were able to cut the overall population by 80 percent in just six months.

But the problem is that we don't fully understand how mosquitoes and the diseases they carry would adapt in response to such experiments. New strains of malaria and other diseases could emerge. Jo Lines, a malaria expert at the London School of Hygiene and Tropical Medicine has described the process as "a series of arms races that the [malaria] parasite has consistently won." Three percent of the offspring from Oxitec's tetracycline-dependent mosquitoes survive—what happens if those bugs breed with wild mosquitoes? It's even possible that the changes we induce in mosquitoes could move into other animals. Horizontal gene transfer could result in midges, gnats and black flies developing the same mutations, including the unfortunate characteristic of dying shortly after hatching—and a mass die-off of insects that provide sustenance to birds, bats, frogs and fish would be a food-chain disaster.

#### HOW WE CAN DO BETTER

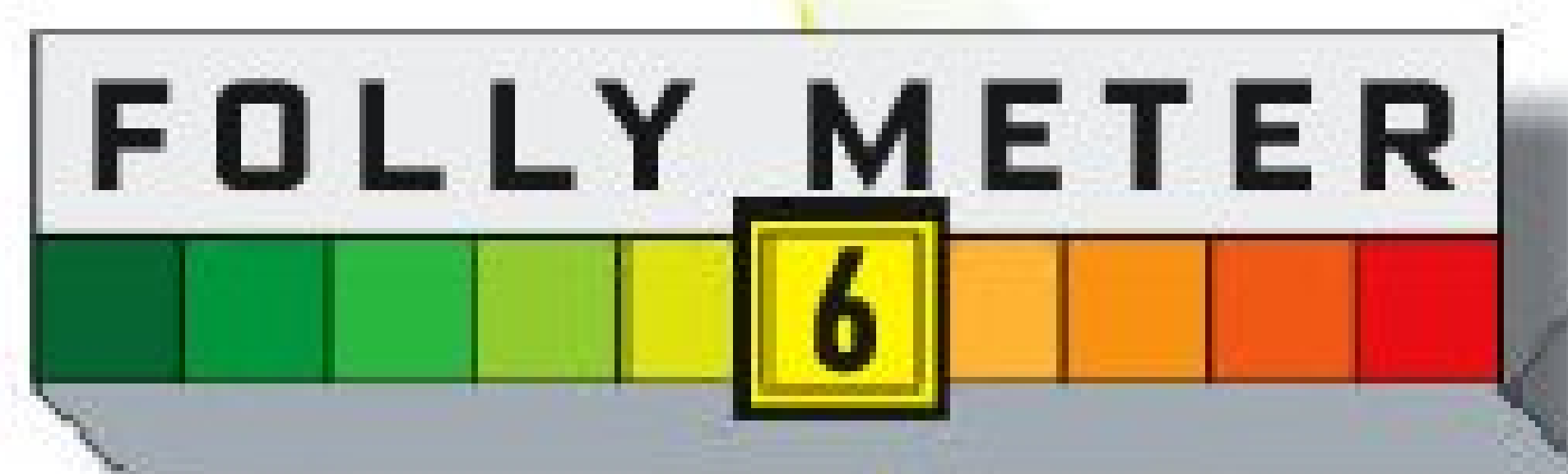
Joe Conlon, a technical adviser for the American Mosquito Control Association, favors using a variety of techniques all at once—dispersing larvicide, which is less environmentally harmful than pesticides that kill adults; planting Ovitraps, which attract egg-laying females; and, where possible, getting rid of the water impoundments where the insects breed.—BECKY FERREIRA

► **FEVER DREAM**  
Critics worry that genetically engineering mosquitoes and releasing them into the wild—one proposed method for controlling the spread of malaria and other diseases—could cause those diseases to become more virulent.

# GENETICALLY ENGINEERED MOSQUITOES COULD SPREAD GENES TO OTHER INSECTS.



# MOSQUITOES



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## AN INTERNET "OFF" SWITCH

The last time someone could shut down the Internet was probably in 1969, when it consisted of two computers. But in recent years, concerned with the possibility of a "cyberattack," Congress has been exploring such an option. In 2009, senator Jay Rockefeller sponsored a bill to give the president the right to "order the disconnection" of "critical infrastructure information systems or networks." That went nowhere, but now there's Senate bill 3480, the Protecting Cyberspace as a National Asset Act of 2010. As its sponsor, Senator Joe Lieberman, told CNN, the bill will allow for the president to order Internet service providers to "disconnect the American Internet from all traffic coming in from another foreign country."

Constructing such a switch would be extremely difficult. Borders are porous. Data packets

originating in, say, Iran or China can enter the U.S. in many different ways—via satellite or submarine cable or packet radio, or routed through other countries. And packets can be "spoofed," or assigned a forged IP address, which means there's no foolproof method to be sure which packets are from home and which from abroad.

Even if it were possible to physically sever the entire U.S. telecommunications system from the rest of the world (and given enough time and money, and the acceptance of a significantly slower Internet, anything could be done), hackers could immediately create a work-around. Consider: Before the Dutch police shut it down last November, the Bredolab botnet commanded an army of 30 million virus-infected zombie computers to send spam. It did so with just over 140 command-and-control servers in the Netherlands, leased through a hosting provider. The man arrested in the case was Armenian. In this era of cloud computing, when anyone from anywhere can

rent servers, including American ones, by the hour, a kill switch would be useless.

In fact, it might be worse than useless; it would present a tantalizing target. Whereas before, it was nearly impossible to disrupt entire networks, now hackers could simply hack into the kill-switch system itself. A more subtle (or cash-strapped) cyberterrorist might simply fake a cyberattack that would trick the U.S. itself into flipping the switch. No one really knows what would happen then—not only would e-mails go undelivered, but ATMs, stock exchanges and the flow of funds of all kinds could be disrupted. And then we would still face another challenge: how to turn the thing back on.

### HOW WE CAN DO BETTER

Don't turn off the Internet. End-to-end encryption (complete encryption of all Internet traffic) would do far more to protect Internet users from spies and hackers, whether they were operating from inside or outside the U.S.—PAUL FORD

▼ **DROPPED CONNECTION**  
Turning off the Internet could shut down financial networks, and it wouldn't be easy to turn them back on.

### FOLLY METER



\*\* Critical error \*\*

Press [F] to begin again.

# SYSTEM FAILURE

All services suspended

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7

# IMMORTAL MICROORGANISMS

Leave it to Darpa, the Pentagon's advanced-research arm, to bring synthetic biology to a new level of creepiness. For 2011, Darpa has dedicated \$6 million to a new program called BioDesign, which according to the agency's budget is an attempt to eliminate "the randomness of natural evolutionary advancement" and create synthetic organisms for specific functions—for instance, microorganisms that clean up oil spills or skin cells that an army medic could use to repair injuries. The twist: Darpa wants organisms "that could ultimately be programmed to live indefinitely." Just in case, they would be equipped with a "self-destruct" option.

But the self-destruct function, which should destroy the cells at a predetermined time or when they left their intended environment, has rarely been tested outside of a lab. There's no way to limit a cell's interaction with other cells or with its environment. There's

no guarantee that the cells won't mutate or replicate incorrectly; synthetic skin cells, for example, could reproduce out of control, causing a cancer-like tumor. Nor is there any way to ensure that these synthetic organisms won't share genetic material with organisms in the environment, giving rise to who knows what kind of microbes. "Engineers hope that they can engineer organisms that are going to behave in a way they predict," says David J.J. Gresham, an assistant professor of biology at New York University. "But as soon as they put it into some selective environment, evolution is going to take over."

Immortal bacteria and unstoppable flu viruses may not be imminent, but the potential for Darpa's synthetic DNA to work its way into other organisms is very real. "DNA transfers from one microorganism to another happen all the time," says Roy Curtiss, the director of the Center for Infectious

▲ **SPACE INVADERS**  
Synthetic organisms like those proposed by Darpa's BioDesign project would be equipped with a self-destruct option, but there is no guarantee they wouldn't escape, mutate, and mate.

Diseases and Vaccinology at Arizona State University. "Worst-case scenario?" says Todd Kuiken, a researcher from the Synthetic Biology Project, an independent study group. "The kill switch doesn't work, and then these things start mutating and mating and splitting—the normal process of an organism." Or the kill switch could work too well: Imagine if a kill-switch-equipped organism managed to form hybrids with microbes essential to the oceanic food chain, triggering a widespread die-off. The consequences could make an oil spill look good.

## HOW WE CAN DO BETTER

There's no stopping synthetic biology, but the research community needs checks and balances. As bioethicists Mildred K. Cho and David A. Relman have argued, designing "effective oversight mechanisms" will be challenging, but essential.—KARLA STARR







# THE POWER BROKER

Arun Majumdar has to decide which researchers will get millions of dollars, and he has to do it fast. As the head of Arpa-E, a supercharged grant program, he must spark an energy revolution within 20 years, or it's lights out for us all

BY TOM CLYNES  
PHOTOGRAPHS BY JOHN B. CARNETT  
ILLUSTRATIONS BY TADAOMI SHIBUYA



## THE MICHIGAN STATE UNIVERSITY

Engine Research Laboratory is usually calm, but by midmorning on this August day, everyone is on edge. Then, a few minutes before noon, assistant engineering professor Norbert Müller gets the call they're all waiting for: The most influential man in energy research is here to see Müller's work.

The tall German shouts the news and trots down the cinder-block hallway toward the front door, drawing a wake of colleagues and graduate students. They flood the sidewalk, standing on tiptoe and squinting through the asphalt's thermal shimmer as an SUV pulls up and a small group gets out. Finally, a tugboat of a man dressed in a blue sport jacket and print tie emerges, and tows his entourage across the parking lot toward the crowd.

Arun Majumdar approaches with restrained economy, as if he has calculated the caloric output of each stride. He steps onto the sidewalk and extends one hand just far enough to reach Müller's, while the other hand stays pressed tightly at his side. "Good to see you," he says.

Müller, one of the world's foremost experts in thermal-fluid engineering, shifts from foot to foot as he meets his guest. Until now, Müller has had to support his research with hard-won five- and six-figure grants from multiple sources. Majumdar gave him \$2.5 million. In Müller's world, Majumdar wields immense power. He has hundreds of millions of dollars to dole out to high-risk projects like the one that Müller is about to unveil. And he's here to check up on his investment.

Majumdar, 47, directs the Advanced Research Projects Agency-Energy, or Arpa-E, a new federal entity that's placing multimillion-dollar bets on Müller and other corporate and university researchers who are looking for new ways to generate, amplify, and store energy. Most researchers struggle

**GRILLING** Majumdar peppers Müller (at center) and researcher Janusz Piechna with technical questions about their Wave Disk Engine.



to make incremental progress on established lines of inquiry, and they mostly attract small grants and investment. But Arpa-E grantees can afford to go after wild, ambitious notions. The results include bacteria that can make gasoline out of carbon dioxide, molten-silicon photovoltaic wafers, and airborne wind turbines.

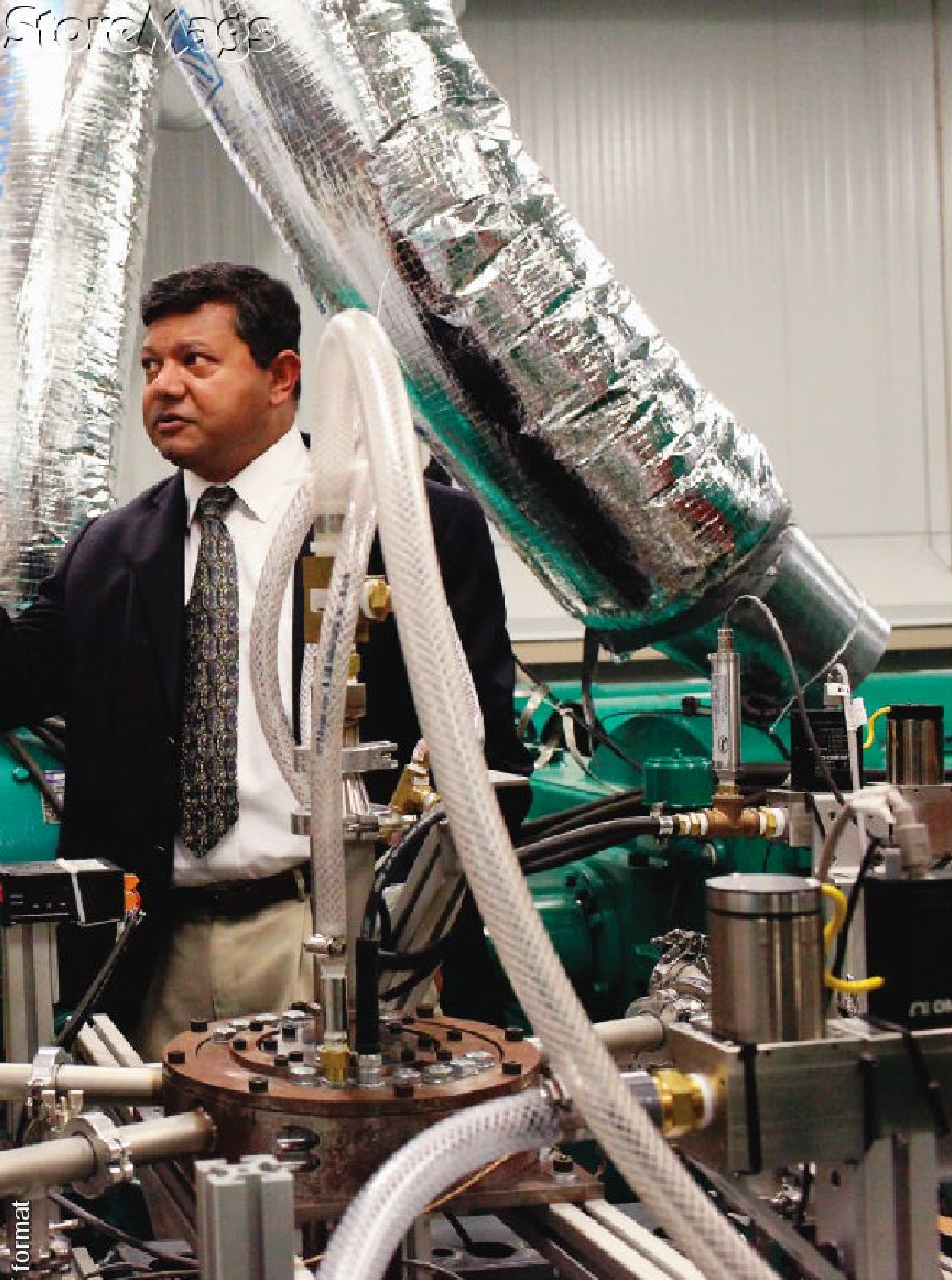
Every few weeks, Majumdar makes the rounds of his grantees to check on their progress. It's not supposed to be an inspection, but Müller is obviously nervous as he ushers Majumdar inside.

**AS A BOY**, Majumdar moved around India constantly. His father, a telecommunications specialist, serviced radio equipment at various airports. Inspired by the aircraft he watched landing and taking off, Majumdar began making wooden gliders and experimenting with his own model airplane designs. Coming out of secondary school, he took the entrance exam for the Indian Institutes of Technology and, among 150,000 applicants, landed one of 1,500 slots. Ultimately, he emerged as the top engineering

# ARPA-E WAS CREATED TO FUND HIGH-RISK ENERGY PROJECTS

COURTESY TERRAVIVA.COM





student at IIT-Bombay. From there, he was offered a Regents fellowship at the University of California at Berkeley, where he studied the science of heat and radiation under thermal expert Chang-Lin Tien, who would go on to become the university's chancellor.

"His philosophy was to work the extremes—either really small or really large," Majumdar says of his

mentor. "That's where interesting science happens." Majumdar eventually became a professor at Berkeley himself, focusing on nanotechnology, transportation and energy conversion. In his spare time, he began advising start-up companies and venture-capital firms in Silicon Valley. Then he joined Nobel Prize-winning physicist Steven Chu at Lawrence Berkeley

## THE OBSESSIVES

National Laboratory as the associate laboratory director for energy and environment.

At the time, Chu was talking about the need for a green-energy incubation program, and in 2006 he proposed that the U.S. Department of Energy create a risk-tolerant agency to fund energy technologies that no private company would dare take a chance on. President Obama appointed Chu to head the DOE in 2008, and Arpa-E received its first \$388 million budget from the \$275 billion American Recovery and Reinvestment Act in early 2009.

### CHU AND MAJUMDAR

modelled their new agency on Darpa, the Defense Advanced Research Projects Agency. The U.S. government created Arpa, later renamed Darpa, after the Soviets launched Sputnik in 1957. The satellite beat the U.S. into space and spurred hysteria over our faltering technological lead. In addition to creating guided missiles and stealth technology, Darpa-funded research produced some of the most useful peacetime inventions in history, including cellphones, GPS and the Internet. "Now our generation is facing three Sputniks of our own," Majumdar explains. "They are energy security, economic security and environmental security."

With energy research starved for government funding since the end of the 1970s oil crisis, Arpa-E's first call for short concept papers in 2009 initiated a tidal wave of proposals—over 3,700—that crashed the DOE computer system. They weren't all cogent proposals. "About 27 percent didn't satisfy the first or second laws of thermodynamics," Majumdar says. Those that did were examined by a panel of hundreds of the nation's top scientists, recruited by Chu. They winnowed them down to 300 finalists, who were invited to submit full proposals. In the end, 37 were selected for first-round grants averaging \$4 million (applicants need to have secured commitments

**LISTENING**  
Majumdar talks with Alan Taub, executive director of research and development for GM, which also receives Arpa-E funds.



for matching funds from non-federal sources). "Note that we didn't break it up into \$100,000 chunks so that we could give out 1,500 grants," Majumdar says. "That's not risk-taking. We needed to award enough to make a substantial difference."

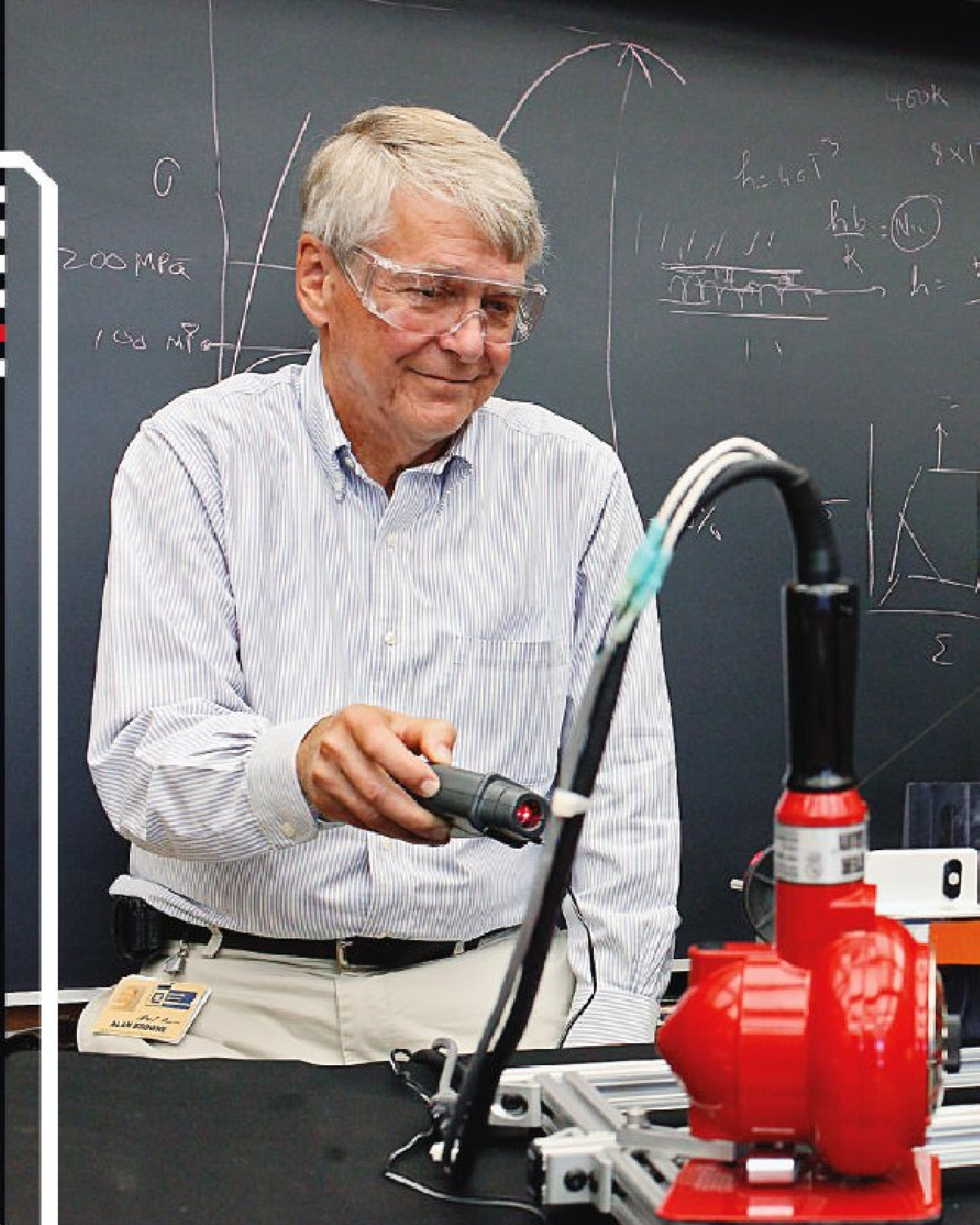
Whereas Darpa has a built-in customer for its creations—the Department of Defense—Arpa-E's creations must survive in the open market. And the grants have tempted some private capital off the sidelines. Venture capitalists and other investors, drawn by the profit potential of technology that had been peer-reviewed and vetted by the country's top scientists, invested some \$33 million in Arpa-E grant winners in the two months following the first award announcements.

After the wide-open first round, the second round focused on next-generation batteries, carbon capture and alternative fuels. A third round concentrated on grid-scale electricity storage, electronics for photovoltaics, and novel approaches to HVAC. Future areas of interest might include thermal storage, power electronics, improvements to photosynthesis efficiency, and new approaches to the extraction of rare-earth elements.

As is the case with Darpa, a large proportion of Arpa-E's pie-in-the-sky energy ideas won't make it out of the lab. "But if just a few of them pay off," says Donald Sadoway of the Massachusetts Institute of Technology, an Arpa-E grantee who is designing a liquid-metal battery, "the impact is enormous." With the right energy breakthroughs, he suggests, the program could lead to a national-security victory over the nation's dependence on oil. At the very least, it could turn sources like solar and wind power into viable parts of our energy portfolio.

**TWO YEARS INTO THE PROGRAM,** some of Majumdar's Arpa-E investments are paying off. Müller's creation, known as

**WATCHING**  
GM's Alan Browne demonstrates the Lightweight Thermal Recovery (LighTER) system for his benefactor.



a Wave Disk Engine, is a cross between a diesel and a turbine that incorporates a shock wave to compress the fuel and transmit its energy. Today Majumdar will see the first working prototype.

Majumdar says Müller is in many ways typical of Arpa-E grantees, or "performers" in Arpa-E's evolving lingo. "Here's a guy with a very good, very important idea who has been working for years with hardly any support. We've lost the art of making new kinds of engines in this country. If we're going to bring back that sort of innovation, we need to encourage people like him to take chances. That's how you put a man on the moon."

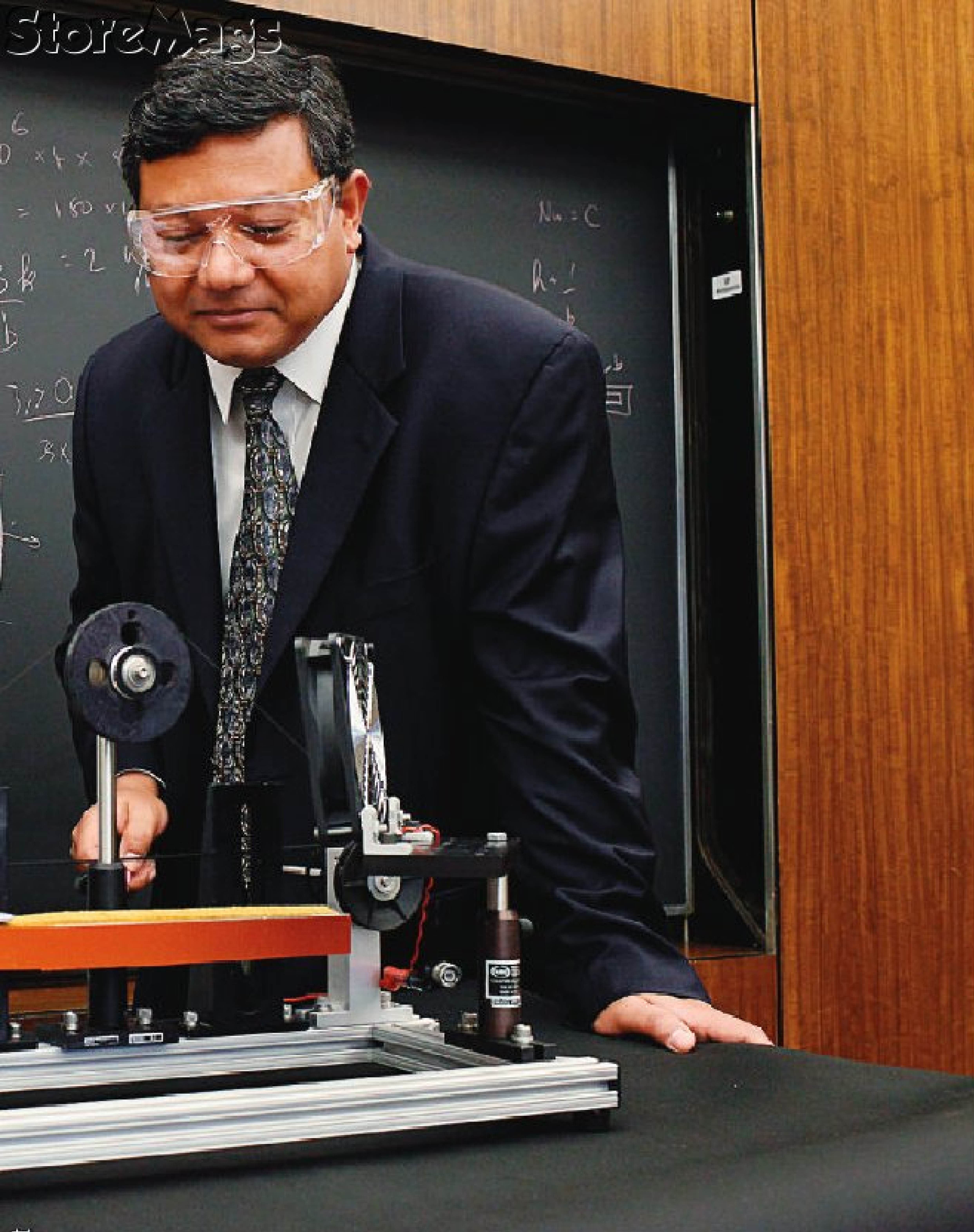
Müller leads Majumdar and his team to his lab, where a circular device the size of a cooking pot rests on a bench. In his grant application, Müller said the Wave Disk would be lighter, cheaper and five times as efficient as conventional automotive

engines, and could give a hybrid car a 500-plus-mile driving range. If those claims seem a little ambitious, that's the point. "If we're going to invent our way out of this crisis," Majumdar tells me, "we've got to swing for the fences. We have to find a way to squeeze 100 years of innovation into the next 20 years."

On seeing the machine, connected to an array of sensors and feeder tubes, Majumdar brightens. Evidently unconcerned with getting grease on his coat, he crouches and fiddles with the device. Then, still on his haunches, he begins to pummel Müller with questions. "Is balancing an issue? Is leakage a problem? What is the optimal speed? Doesn't the shock wave produce entropy?"

It's an onslaught. "To understand the role of the shock wave, imagine a bomb," Müller says, stammering slightly. "Well, maybe that example's not so good." He pauses. "Imagine a bumblebee. It's too heavy to fly





## “WE’VE LOST THE ART OF MAKING NEW ENGINES IN THIS COUNTRY”

normally with those little wings, so it creates pressure waves that travel with sonic speed, compressing the air to boost lift. Inside the wave disk, we use a shock wave to compress the fuel and utilize it to convert energy into work.”

Satisfied, Majumdar nods and fires off another question, then another. Later he will tell me that he has integrated “constructive confrontation,” a concept he borrowed from former Intel CEO Andy Grove, into the culture of Arpa-E. “When we’re talking science

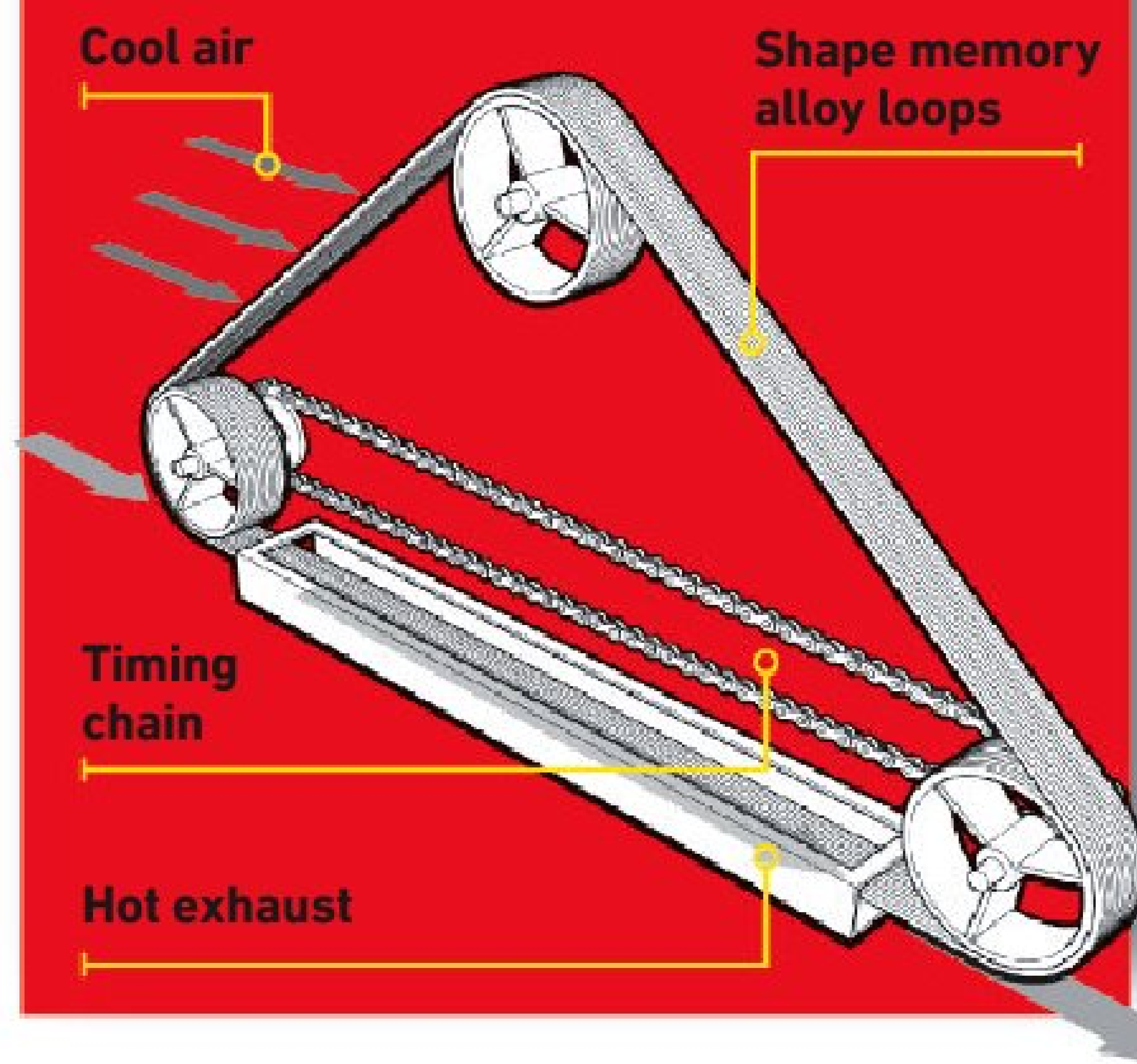
and engineering and evaluating new programs and proposals, I’m no longer the director,” Majumdar says. “We debate things out as equals, and the good, strong ideas are the ones that survive. That’s the way science works best.”

Müller slowly senses that Majumdar is trying to improve his work, not disparage it. He takes the questions point by point, his nervousness evaporating. We move behind a window of protective glass and, on Müller’s cue, a grad student at a computer terminal

### THE OBSESSIVES

## WHAT A GRANT BUYS

Arpa-E grants have funded every kind of energy research. One grantee used the money to design a single-step process for manufacturing solar cells. Another created a flying wind turbine. And while the car industry remains focused on lithium-ion batteries for electric and hybrid vehicles, Arpa-E grants have funded a zinc-air flow battery and ultracapacitors made of carbon nanotubes. In the thermal-recovery system (below and at left), a shape-memory alloy shrinks and expands, turning pulleys to boost power in a car’s engine using only the heat of its exhaust.



energizes an electric motor to start the engine’s internal blades spinning. As the tachometer moves past 1,000 rpm, then 1,500, the student glances at Müller.

“Let’s not start combustion just yet,” Müller says. “Wait until the speed stabilizes.” He glances toward Majumdar, then back at the screen, as the tach creeps toward 2,000 rpm. Finally, he nods at the student: “OK, let’s see if Frankenstein comes to life.” As we watch from behind the glass, the grad student feeds fuel and ignition to the engine. The wave disk begins to shake, then sputters to life. As it hums away on the table, a smile creeps across Majumdar’s face. “It’s got a heartbeat,” he says.

Majumdar begins to relax. His technical questions keep coming, but they’re like those of a proud dad. He chats up the grad students—“Do you have an energy club on campus yet?”—and talks to Müller about his prospects for

(CONTINUED ON PAGE 64)



# INSTANT EXPERT

EVERYTHING YOU NEED TO KNOW. NOTHING YOU DON'T.

## TRAINED CANCER KILLER

Medicine harnesses the might of the immune system to defeat prostate cancer

### STATISTICS

2

Rank of cancer as a cause of death in the U.S.

1 IN 6

Chance that a man will develop prostate cancer in his lifetime

1 IN 5

Chance that a man with prostate cancer will qualify for Provenge

\$93,000

Cost of a single course of Provenge without insurance or Medicare subsidy

**DOCTORS** have been trying to enlist the immune system of patients in the battle against cancer since at least 1893, when physician William Coley of New York Cancer Hospital injected bacteria into a patient's body in the hopes that it would spur the immune system to fight the bacterial infection and cancer cells alike. The tumor disappeared, and the patient lived for another 26 years. But

immunotherapy was eclipsed by radiation and chemotherapy, which showed more-immediate and reproducible results.

Last April, Provenge became the first FDA-approved treatment that retrains the immune system to target cancer. Scientists have tested it only on subjects already near death, in this case men whose tumors had spread beyond their prostate. Those who took Provenge

lived an average of 4.1 months longer than those who didn't. Now researchers at Dendreon, which manufactures Provenge, are looking into whether it can stop the cancer from spreading beyond the prostate. If that can be done, says Paul Schellhammer, a urologist at Eastern Virginia Medical School who studied Provenge in clinical trials, the patient will usually survive. —CARINA STORRS

### HOW TO BATTLE CANCER WITH A VACCINE

ILLUSTRATION BY MEDI-MATION

PAP-coated APC

Prostate acid phosphatase

Antigen-presenting cell

Activated T-cell

Inactive T-cells

#### 1. THE PRINCIPAL CHARACTERS

For the immune system to target cancer, it first must recognize it, which it can do by using **antigen-presenting cells (APCs)** to present information about the protein markers—antigens—found on cancer cells to the T-cells that will eventually destroy them.

#### 2. KNOW YOUR ENEMY

Scientists begin this process by harvesting APCs from patients and incubating them in a flask containing the antigen **prostate acid phosphatase (PAP)**. The APCs swallow up PAP and present the antigen on their surface.



Dying cancer cell

Cancer cell

## FAQs

**HOW IS PROVENGE DIFFERENT FROM CURRENT IMMUNE THERAPIES FOR CANCER?**

Immune therapies have been around for years. Some provoke a general immune response, like the FDA-approved drug interferon alpha does for leukemia. Others are antibodies—Herceptin binds to breast-cancer cells, hindering their growth. But the effects of those therapies last only as long as they remain in the body. Provenge is the first drug that retrains immune cells to fight cancer after treatment.

**WHAT WILL BE THE NEXT CANCER VACCINE TO HIT THE U.S. MARKET?**

Two vaccines effective against non-small-cell lung cancer, the most common type of cancer to affect that organ, are the most likely. In a 2004 study, patients who got Stimuvax, manufactured by Merck KGaA, lived on average 17.3 months longer than unvaccinated patients. A similar vaccine by GlaxoSmithKline is also in clinical trials. "Within five years, I think we'll see several more vaccines approved," says James Gulley, a medical oncologist at the National Cancer Institute who is studying a new type of prostate-cancer vaccine called Prostavac. Scientists are currently testing vaccines against ovarian, liver and pancreatic cancers. Several cancer vaccines have already been approved outside the U.S., including ones against skin and colon cancers.

**WILL VACCINES EVENTUALLY PREVENT CANCER?**

Maybe. But giving a vaccine to the masses, including those who would never otherwise get cancer, makes sense only if the vaccine is extremely safe and cheap, Gulley says. Tests for predicting cancer risk could help doctors decide who to immunize.

**3. ATTACK THE TUMOR**

With PAP fragments studding their surface, the primed APCs now serve as the Provenge vaccine. After doctors inject the APCs back into the patient, the APCs circulate in the bloodstream. There, they train the body's **T-cells** to attack any cells that display PAP, including prostate-cancer cells.



# The Second Green Revolution

BY FREDERICK KAUFMAN  
PHOTOGRAPHS BY  
JOHN B. CARNETT

A century of agricultural innovation has vastly increased the amount of food on Earth—and with it, the total population. But the first green revolution is proving unsustainable, and hunger is on the rise. Now keeping the world fed will require an unlikely alliance between genetic engineers and organic farmers

AMONG THE TREE-LINED BIKE PATHS, automated livestock pens and darkened lecture halls of the University of California at Davis, a tiny room holds a weapon of mass destruction. Here, behind locked doors, sits a chunk of *Xanthomonas*, a bacterial blight that has decimated rice harvests in China, India, Indonesia, Malaysia, the Philippines, Thailand, Vietnam and West Africa. Since the passage of the Bioterrorism Preparedness and Response Act of 2002, the U.S. Department of Agriculture has deemed *Xanthomonas* a “select agent,” which meant that in order to enter I had to produce a photo I.D., sign a series of documents, and suit up in a disposable lab coat. Within the restricted area, a staff researcher snapped on a pair of rubber gloves, unlocked an incubator, and extracted a petri dish of yellowish goo, which he held a few inches from my outstretched hands. “I can’t let you touch it,” he said.

AMERICAN  
GENETIC  
Scientist Pamela  
Ronald and her  
husband, organic  
farmer Raoul  
Adamchak, are  
cultivating a new  
way to end hunger.







## THE FUTURE OF FOOD

It may have looked like nothing more than a lump of mold, but the pathogen that could rot the grain that feeds half the world had also introduced a new and ominous twist to the story of mankind's greatest agricultural triumph: the green revolution. Since the days of Thomas Malthus, many scientists have feared that the Earth could not produce enough food to sustain its rapidly growing population. While some contended that science would find a way to overcome such limits, the Malthusians pessimistically maintained that the world possessed a finite amount of arable land and that each acre of that land could produce only a given amount of harvest in a given growing season. Keeping pace with an exploding population meant either creating more land to farm or making the existing farmland more productive. And it was the green revolution that introduced the agricultural breakthroughs that provided the means to do both. Innovations in dam construction and irrigation increased the amount of arable land. At the same time, scientists discovered how to use fossil fuels to create

science of genetics has proved sustainable.

That was why I had come to the Ronald Laboratory, the eponymous workplace of Pamela Ronald, professor of plant pathology and co-author with her husband, Raoul Adamchak, of *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food*. It was becoming clear that maintaining Earth's current population—much less increasing it—would require a second green revolution, and that this next revolution could not draw on the same finite resources as had the first. Scientists must now figure out how to do more with less, and that figuring was going on here, in Professor Ronald's genetics laboratory.

### THE DOOR OF THE CONTAGION CHAMBER

opened into a large, light-filled room, where Ronald guided me through an antiseptic wilderness of sterilized glassware, centrifuges and fume hoods. The machines rumbled and sputtered and whirled as scientists hunched over their beakers and flasks and test tubes of clear and yellow liquids. To my left, one of a dozen lab

## IF THE FIRST GREEN REVOLUTION DEPENDED ON BILLIONS OF TONS OF RAW MATERIALS, THE SECOND GREEN REVOLUTION WILL DEPEND ON BILLIONS OF GIGABYTES OF RAW DATA.

powerful synthetic fertilizers to make that land more productive. Chemists found new ways to battle pests and viruses, and geneticists discovered how to make the plants themselves hardier and more nutritious. More land produced more food, and the result of all this abundance was major, seemingly sustainable population growth. In 1911, when German chemist Fritz Haber first demonstrated how to create synthetic fertilizer, the Earth's population was about 1.7 billion. Since then, it has doubled, and then doubled again.

Now billions of people rely on the continued success of those four innovations: irrigation, fossil-fuel-based fertilizer, chemical pesticides and genetics. But the exorbitant expenditures of resources that guaranteed the success of the first green revolution may no longer be possible. After all, the Malthusians were not wrong about the limits of growth. Today we are rapidly depleting and polluting our sources of freshwater, and much like the planet's population, the price of oil has also doubled and doubled again. Nor can anyone ignore the virulent agri-clouds of insecticide and herbicide, much less the agricultural runoffs that have produced dead zones in our oceans. Of all the green revolution's innovations, only the

researchers and students labored next to a small white box of clear plastic containers labeled "Transformants," while gazing every so often at a document that possessed an arresting single-word title: "Mutant." Here was the act of genetic alteration at its most basic level: the collection and analysis of unprocessed data.

Ronald and her colleagues have deconstructed the genetic code that could prevent *Xanthomonas* and other pathogens from unleashing havoc on the world's food supply, just as they have crunched the molecular numbers to reveal which rice genes will allow a crop to survive catastrophic flooding. In a world beset by drought and hurricane, disease and soil erosion, the science of fighting hunger is becoming an information science, ever less bounded by material limits. If the first green revolution depended on billions of tons of raw materials, the second green revolution will depend on billions of gigabytes of raw data.

Not everyone is welcoming this development. A loose grouping of activists—the local-food movement, the slow-food movement, the family-farm movement, the organic-food movement—perceives genetically altered crops as its nemesis, the embodiment of a corporate agribusiness model that will sweep away

**LIFE SOURCE**  
Rice (from  
top to bottom:  
callus tissue,  
protoplasts,  
and seedlings)  
sustains the  
diet of half the  
people on Earth.











our planet's biodiversity, engender a death spiral of environmental degradation, and increase health risks for consumers at the same time as the largest players in a transnational food cartel use patent law to stash away untold millions of dollars, euros and yuan.

Rather unsurprisingly, research scientists have returned the food activists' scorn with counter-accusations of arrogance, ignorance and elitism. And the entrenched opposition between biologist and foodie has led to the dead end of dichotomy: the widely held notion that a hungry world will have to choose between organic or conventional crops, the past or the future, whole foods or molecules.

Ronald grew up in Northern California, where her hobbies included skiing in the Sierras and cloning her mother's African violets. She has no interest in picking sides. "There are a lot of great ways to minimize the ecological damage done by agricultural systems," she said. "But not all of them are implemented when needed." She showed me a book, *Banana: The Fate of the Fruit That Changed the World* (based, as it

**NOT FAR FROM RONALD'S SPOTLESS LAB,** her husband and co-author, Raoul Adamchak, treads beneath the open sky. Adamchak has been the farmer-in-chief of the five-acre U.C. Davis student Market Garden since 1996, and it is there that he is enacting a future that at first appears to be precisely contrary to the high-speed, data-driven approach that defines his wife's labors. On this bright summer morning, he was wearing a straw hat from Ghana and muddy farmer boots, and when I asked him about the role organic farms would play in the next green revolution, he did not lead me to a computer screen but to an earthy plot of cowpeas. "The big picture is that in an environmental sense, agriculture is devastating," he said. "Wherever you have crops, you don't have wildlife or native ecosystems or wild plants. You have plants that feed us. So the trick is to make farming as least harmful as possible and still produce a lot of food."

As an organic farmer, Adamchak was especially interested in the molecular workings of carbon, nitrogen, phosphorus and potassium compounds,

## FARMERS EXTRACT ANCIENT SOLAR ENERGY (THAT IS, OIL) FROM ONE HOLE, CONVERT IT TO FERTILIZER, TRANSPORT IT ACROSS GREAT DISTANCES—AND THEN POUR IT RIGHT BACK INTO ANOTHER.

happened, on an article that originally ran in *POPULAR SCIENCE* in 2005). "One hundred million people in East Africa alone rely on bananas for their nutritional needs," she said, but since by far most edible bananas are cloned, the fruit possesses a very limited gene pool, which makes the global banana supply susceptible to obliteration by a single contagion. Many anti-GMO activists had raised alarms about this very problem, and now a banana-killing bacterial disease was making its way through eastern Africa. But Ronald pointed out that her own genetic investigations could be useful in fighting that blight. "Rice is distantly related to the banana," she said, "and our hypothesis is that the same rice gene that gives rice immunity to *Xanthomonas* will function in the banana."

I mentioned the import bans on GM crops that had kept grain from entering Zambia and Zimbabwe even as their citizens suffered through the drought of 2002–3. Would the technology that could create a GM banana also prove to be its downfall? "You want the most appropriate technology for any particular situation," Ronald said. "Everything we care about is embedded in these plant genomes. We would be foolish not to use this information for the public good."

and the problem of holding these chemicals within the Earth's biomass to feed succeeding generations of crops—rather than allowing them to wash away and fuel unwanted fields of algae that plunder oxygen from the world's lakes, streams and oceans.

Nothing has done more to transform the land, it turns out, than the annual tithe of energy that we demand from it. This energy drain helped create the Dust Bowl of the 1930s and has efficiently wrought a dead zone in the Gulf of Mexico that on some summers reaches the size of New Jersey. And all the efforts of agri-tech could not change the essential fact that everything that grows must first take its energy from the sun, which fuels the photosynthesis that grows the plants, which then die and transfer their energy to the soil, which sustains the crops that eventually fuel the hungry engine that is the human stomach. But conventional agriculture is a terribly inefficient means of transferring energy from sun to stomach. Commercial farmers extract ancient solar energy (that is, oil and other fossil fuels) from one hole in the ground, convert it into fertilizer, transport it across great distances—and then pour it right back into another hole in the ground. This convoluted scheme

**IN THE GRAIN**  
At the U.C. Davis greenhouse, transgenic rice carries genes that confer flood tolerance and resistance to blight.



THE FUTURE OF **FOOD**

contributes to erosion, wastes considerable energy, and creates pollution at every stage. But cover crops such as cowpeas, Adamchak explained, could help eliminate the farmer's need for synthetic fertilizers. Using a form of bacterial symbiosis, they breathe in nitrogen from the air already around them and fix the molecules in their roots, stems and leaves. When they die, that nitrogen—the all-purpose, basic fertilizer—resolves into the soil. In this way, cover crops help keep the energy cycle local.

I asked Adamchak what he made of the genetic work his wife did. He said that in our closed-loop world of limited resources, where every expansion of fertile farmland demands a corresponding decrease in natural habitat, he and Pamela Ronald had reached a new perspective on the future of food: that it will be neither organic nor molecular but an agro-ecological synthesis of both bodies of knowledge. “As a farmer, I’m not quite sure how healthy it is to look backward for solutions to problems,” he said. “A molecular understanding will help solve problems down the road.”

I considered a future in which the science of

made to resist freeze, others to resist flood, and some to resist deadly rice pathogens like *Xanthomonas*. All of which could conceivably be grown using the organic methods I had just witnessed.

Then, as if to materialize my thoughts, I came across a vast greenhouse. Beneath the great glass roof, full-grown rice plants shot up from black plastic paddies packed with mud and flooded with brown-gold water. The yard-tall flat plants were rough-skinned and pointy-tipped, top-heavy with beautiful green kernels of rice. Each plant had its own label, and I stopped before a particularly tall and vigorous clump called Xa21-106/TP309. This was the first disease-resistant transgenic rice Ronald created, one that she has cultivated in her laboratory for more than a decade. “Many years ago, we gave the Xa21 gene to Chinese breeders,” she had told me. “It was scheduled to be released two years ago, but the agricultural ministry still has not approved it.”

Today, while the Chinese government bolsters intellectual-property protections for its seed industry, Xa21-106/TP309 still languishes in the ministry's

## NO MATTER HOW MANY ADVANCES WE MAKE IN GENETICALLY MODIFYING OUR SEEDS, THEY WILL STILL NEEDED TO BE PLANTED IN THE EARTH, WATERED, WEEDED, RIPENED, AND HARVESTED.

genetic modification exploits all the micro-information available from a plant's genome even as the science of organic farming exploits the macro-energies of the sun, the earth and water. Unlike synthetic fertilizers and chemical pesticides, both the gene and the Earth's energies had always already been there, waiting. Both methods of making food took advantage of what was closest at hand. The farmer interrupted my thoughts as he held out a flimsy green plastic pint basket. “You’ve got to pick now.”

So I bent over a row of tomato vines and worked my fingers through a tangle to reach the grape-size Sun Gold tomatoes, a crop of contradictions. These tomatoes were organic, but they were genetically altered too. And as the ooze from broken stems stuck to my fingertips, I contemplated the entrenched conflict between the activists and the scientists, the mystics and the agribusinessmen. No matter how many advances we make in genetically modifying our seeds, they will still need to be planted in the earth, watered, weeded, ripened, and harvested.

As I walked away from Adamchak's organic garden, I imagined a world filled with thousands of customized, gene-spliced, open-source, freely available grains—some

bureaucracy, where it awaits the go-ahead for commercial development. Despite the ravages of Asian rice blight, and despite the fact that the virus has helped add millions to the roster of those who are hungry or starving at this moment, Pamela Ronald's Xa21-106/TP309 has yet to become an officially commercialized crop. If this rice embodied the future of food, what on earth was holding it back?

**THAT EVENING, I MET** Ronald and Adamchak at a restaurant tucked into a quiet corner of downtown Davis. We settled around a wooden table surrounded by bottles of rosé and riesling, blanc de blanc and semi-seco, cabernet, port and prosecco. An arrangement of dead wheat sat on the mantle above us, the stalks of yellowed grass tied together and flared like a bouquet of flowers. Our flights of wine arrived in test-tube racks. “It’s all a biology experiment,” Adamchak said.

As we ate our organic chips and guacamole, Ronald and Adamchak explained that farmers have always modified food genes. Since the days, some 10,000 years ago, when humans first began to save the seeds of one plant variety and discard those of another, they favored the ones that produced the plumpest grains,

**GREEN GENES**  
One result of 10,000 years of agricultural innovation: the planet's farmers can choose from some 120,000 varieties of rice.





the earliest maturities, the highest yields. They also selected hardy specimens, varieties that could withstand the heat and the cold and all the blights that cursed and killed their crops. Even if none of the prehistoric paddy-technologists of, say, China's Yangtze River valley could understand why only the merest sampling of the Earth's increasing varieties of rice did not wilt and die when infected with the stuff that looked like a lump of mold, the blight that eventually came to be known as *Xanthomonas*, these generations of anonymous men and women were nonetheless gathering information and acted on their findings. They were farmers, but they were also seed scientists, consciously transforming wild grasses into harvestable grains.

In 1866, the science of seed selection took a major step forward. A monk named Gregor Mendel compared the characteristics of some 30,000 different pea plants and demonstrated the so-called factors of inheritance, the dominant and recessive genes that form the basis of modern seed hybridization. Mendel's calculations transformed the mysteries of plant lineage and the crapshoot of cross-pollination from guessing games to matters of statistics—a transformation that perfectly suited the times. Soon after Mendel's discovery, news of famine in India hit the London broadsheets, and the perennial fear of global hunger once again began to pervade American and European consciousness. All of which may explain why, when Luther Burbank published his *New Creations in Fruits and Flowers* in 1893, newspapermen dubbed him a "seer." Americans marveled at the geneticist's pitless prune, his spineless cactus and his white blackberry. And when radio eventually bought the rights, "the Man with Green Fingers" was portrayed by none other than Lionel Barrymore. How was it, then, I asked the couple, that genetic modification had become such a villain to so many within the food movement?

As it turned out, Burbank's popular success had far-reaching consequences. The Plant Patent Act of 1930 amended U.S. patent law to provide botanists with economic incentives for their innovations and transformed agriculture from a science based on information to a business based on information. Since the passage of the act, each new variety of crop has made possible an income stream from a new form of intellectual property—property that could be bought, sold, licensed, or monopolized. Eventually the demand for new varieties took on its own logic; hardiness, resistance to pests, and greater nutritional value were still important, but so too was newness itself. Seed manufacturers sought hundreds and thousands of varieties to patent and sell, and they pursued more and more advanced methods of creating the next best seed, including radiation-induced asexual mutation and cloning. Of course, the vast majority of today's supermarket shoppers remain

(CONTINUED ON PAGE 671)



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# HOW 2.0

TIPS, TRICKS, HACKS AND DO-IT-YOURSELF PROJECTS



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Build a device that makes rice cakes



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What you can do with Dropbox



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Make an inexpensive laptop stand

YOU BUILT WHAT?!

## TOOLING AROUND

A drag racer that hits nearly 50 mph, powered by disc cutters



Barry Lee was sitting at his desk one day when his boss at British retailer Toolstation stopped by with a new assignment. He had heard about a drag-racing series for vehicles propelled by power tools, and he wanted to win. "You're the man to do it," he

told Lee, an IT support manager. Three years, countless man-hours and several versions later, Lee finished Bolt Lightning, a disc-cutter-powered dragster with one speed: fast.

Lee got the job because of his experience working on

**TRACK STAR**  
Bolt Lightning reached 46 mph in winning the Silverline Power Tool championships by about three tenths of a second.

cars, but he also recruited colleagues with engineering and electronics backgrounds. One of their models for an earlier race was a two-tool setup, but they wanted more power to ensure a victory, and that meant more tools. Four disc cutters didn't seem like enough, while eight added too much weight. In the end, they settled on six.

After several months of chassis design, early

(CONTINUED ON NEXT PAGE)



## THINGS

# 5 THINGS THAT CAN HELP YOU DECORATE YOUR HOME

## 1 EASY STYLE

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## 2 DOT YOUR EYES

Turn any picture into a megasize poster. The Rasterbator (*the-rasterbator.en.softonic.com*) blows up any uploaded image into a large raster graphic (that is, a bunch of pixels). It spreads those pixels across several pages—or several hundred—in a PDF that you can download, print, and assemble on your wall.

## 3 DREAM COAT

Take a picture of objects in your home, fabric swatches or even an awe-inspiring sunset, and use the free iPhone apps Ben Color Capture and ColorSnap to find paints that match them, as well as nearby Benjamin Moore and Sherwin-Williams stores to buy them.

## 4 SMOOTH MOVES

Move the couch while you're still sitting on it. Create a virtual 3-D mock-up of your pad with mydeco (*us.mydeco.com/design*), and play around with new furniture arrangements so you can save the heavy lifting until you've found the perfect layout.

## 5 DESIGNER IMPOSTERS

Try out designer furnishings without a designer—or the furnishings. Download the free Atelier Pfister app for iPhone or iPad, and photograph a room. Then choose pieces from top designers, drop them in the pic, and change their orientation and placement to see exactly how they'll look.

—AMANDA SCHUPAK

# HOW 2.0 YOU BUILT WHAT?! (CONTINUED FROM PRECEDING PAGE)

last year Lee and his team acquired some 6.2-horsepower gas-powered Makita disc cutters. They experimented with a mock chassis by screwing together broom handles and pieces of wood, and stacked two rows of three disc cutters instead of installing them all in a single row as they had originally planned. With the cutting discs removed, the motors would turn fan belts attached to the driveshaft, generating 37.2 total horsepower.

The next six months were a blur of wiring, body-forming, chassis fabrication—they scrapped the wooden version for steel—and hunting for parts. "It was live, eat, sleep, drink, and breathe dragster for a while," Lee says. But this summer, Bolt Lightning dusted more than a dozen competitors, winning the Silverline Power Tool championships with Lee at the wheel. The boss was pleased.—GREGORY MONE

## HOW IT WORKS

TIME: 11 MONTHS  
COST: ABOUT \$2,500



**MORE POWER** A seventh disc cutter was added to increase acceleration.

### ENGINES

To start the kart, Lee first has to pull the ripcord on each of the six disc cutters, all of which run on two-stroke, fuel-powered engines. "It gets crazy noisy," he says. At that point the engines are idle.

### ELECTRONICS

Bolt Lightning uses an electronic throttle system. Once the engines are idling, Lee straps into the seat and hits a foot pedal that flips two switches located underneath. This activates electronic motors, normally used in the door-locking mechanisms in cars, that the team added to the tools, flicking on the throttles. There's no accelerator or shifting of gears, so as soon as the switches are flipped the throttles go from 0 to 100 percent.

### BODY

Lee says the builders chose a three-wheel design to save weight and allow easy access to the drive mechanism at the back. But they weren't totally focused on staying light; the roughly 450-pound chassis was

### DRIVING FORCE

Fan belts spin the vehicle's power shaft.



engineered for strength. The front end began life as a go-kart, but Lee and his colleagues cut and molded the rear of the kart, the roll cage and the engine housing from different kinds of high-strength steel.

### HANDLING

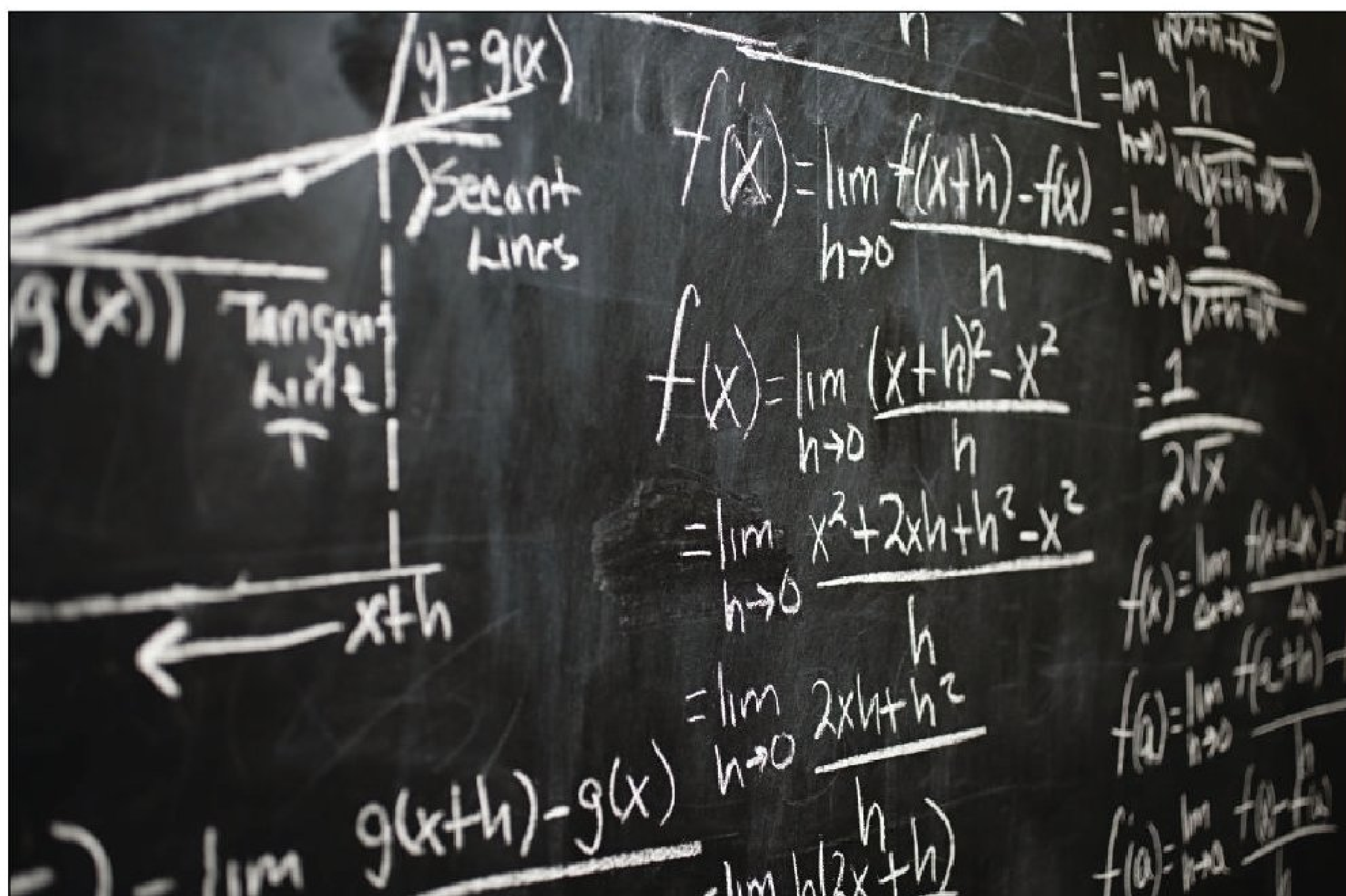
The dragster is slightly unstable through turns because of the three-wheel design, and the fact that half the engines sit at the height of the driver's shoulders. Lee has had it up on two wheels on a few occasions, he says, "but in a straight line, it's very stable."

### THE RACE

The main race takes place on an outdoor runway in Ilchester, England. Entrants complete several 100-meter straightaway sprints over two days, and Bolt Lightning turned in the top times and speeds. Lee used an Android app on his smartphone to clock the top speed as he drove. The runway had extra room, which was fortunate: The converted go-kart does have a brake, but it's designed for a much lighter and less powerful vehicle.

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## HOW 2.0 BUILD IT

# WISE CAKES

The hosts of *Food Jammers* make a version of a multimillion-dollar commercial grain puffer—for about 50 bucks



**The machinery** that snack and cereal companies use to transform rice and other foods into puffed snacks is expensive and operates at extreme pressures and temperatures. Since you can buy the resulting cheese puffs, rice cakes and toasty oat cereals anywhere, why try to make them ourselves? Because we were curious whether we could figure out a cheap way to crack the code of puffing technology. Plus, we like to build elaborate machines and to blow things up, even if it's only



**WARNING**  
Using tools at high pressures with flames can be dangerous. The puffing action and release of locking pliers can move hot parts quickly. Play it safe, wear proper protection, and secure loose articles and moving parts. Keep fire extinguishers handy.

spelt grains and millet cakes.

The science behind puffing is simple. Heating the moisture inside of a grain creates pressure and builds up steam, which is trapped by the grain's hull or shell. When that hull suddenly fails, everything inside it expands in a blast, transforming the grains into a crispy, porous mass; the best example of this is popcorn. Some grains can fuse together, making a cake.

Not all grains are easily puffed, though. Try to puff rice or wheat

berries in this way, for example, and they just burn. Two things are required to get almost any grain to puff. You need an optimal amount of moisture inside the grain, and you must artificially make a popcorn-like shell that can temporarily hold steam under pressure and release it suddenly. We built a metal shell using a pipe, a rod and a plate to mount the pipe on, forming a bottom to clamp against, like a piston in a cylinder. Using vise grips, we put the shell over a butane burner, clamped





**DIY SNACKING** The ideal pressure and temperature vary with each grain, so trial and error is key. Too much pressure, and you get explosive fragments. Too short or soft, and the grains will be raw and inedible. If you take too long, they'll burn. Once you have the mix and motions right, try adding some seasonings.

it tightly, and then unclamped it to make it puff. At high temperatures, you have 10 to 20 seconds when the grains puff before they start to burn. We puffed millet, wild rice, sorghum, barley, and white and brown rice. We called the results "vise cakes."

Our equation for the process looks roughly like this: 150 psi (pressure) and 480°F (heat) x 12 seconds (time) + sudden release back to atmosphere = 1 vise cake.

Last year we built a rig to make mini vise cakes, which worked well,

but it took a long time to produce a large quantity. So this time we increased the scale, creating a design that could make the cakes with a 2.5-inch diameter. All told, it cost us only \$57. Our design requires at least four hands to operate, though why puff solo when you can puff in a group? Besides, you're saving a good million bucks or so off the price of a commercial machine.

*Micah Donovan, Christopher Martin and Nobu Adilman (facing page, from left), are the hosts of Food Jammers on the Cooking Channel.*

## HOW TO MAKE A GRAIN PUFFER

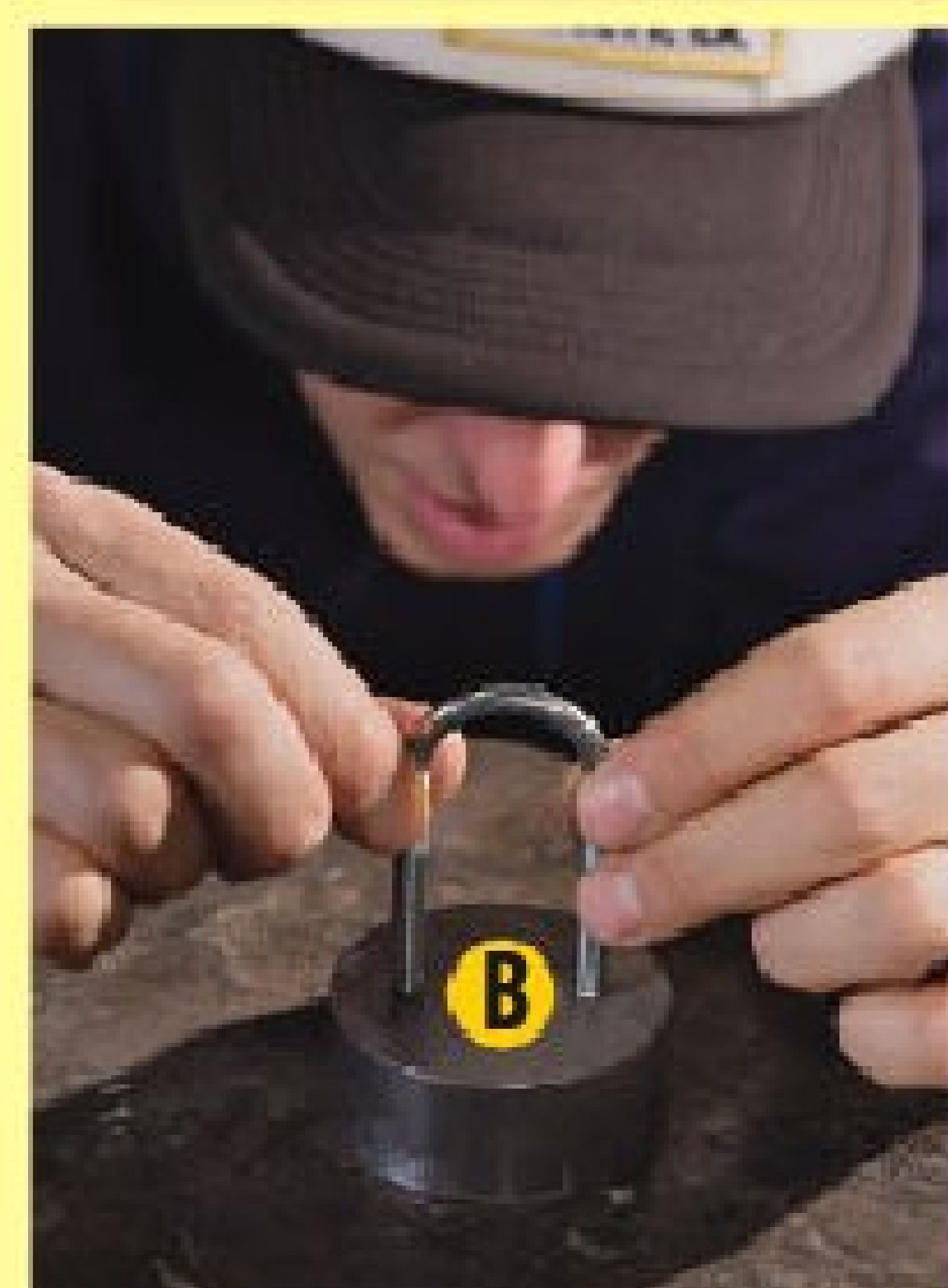
TIME: 3 HOURS COST: \$57 EASY      HARD

**1** Add a cup of grain to a quarter-cup of water in a sealed container overnight in the refrigerator. This gets the grain moisture up to at least 20 percent.

**2** Cut a three-quarter-inch ring slice [A] off a seamless-steel tube with a 2.5-inch inside diameter. File the edges smooth, and wash them. Mount the ring to the center of a flat metal plate (we elected to weld it).



**3** Cut a three-quarter-inch slice of round stock that fits snugly inside the ring but can be pulled smoothly in and out. File the edges, sand the outside smooth for a proper fit, and wash.

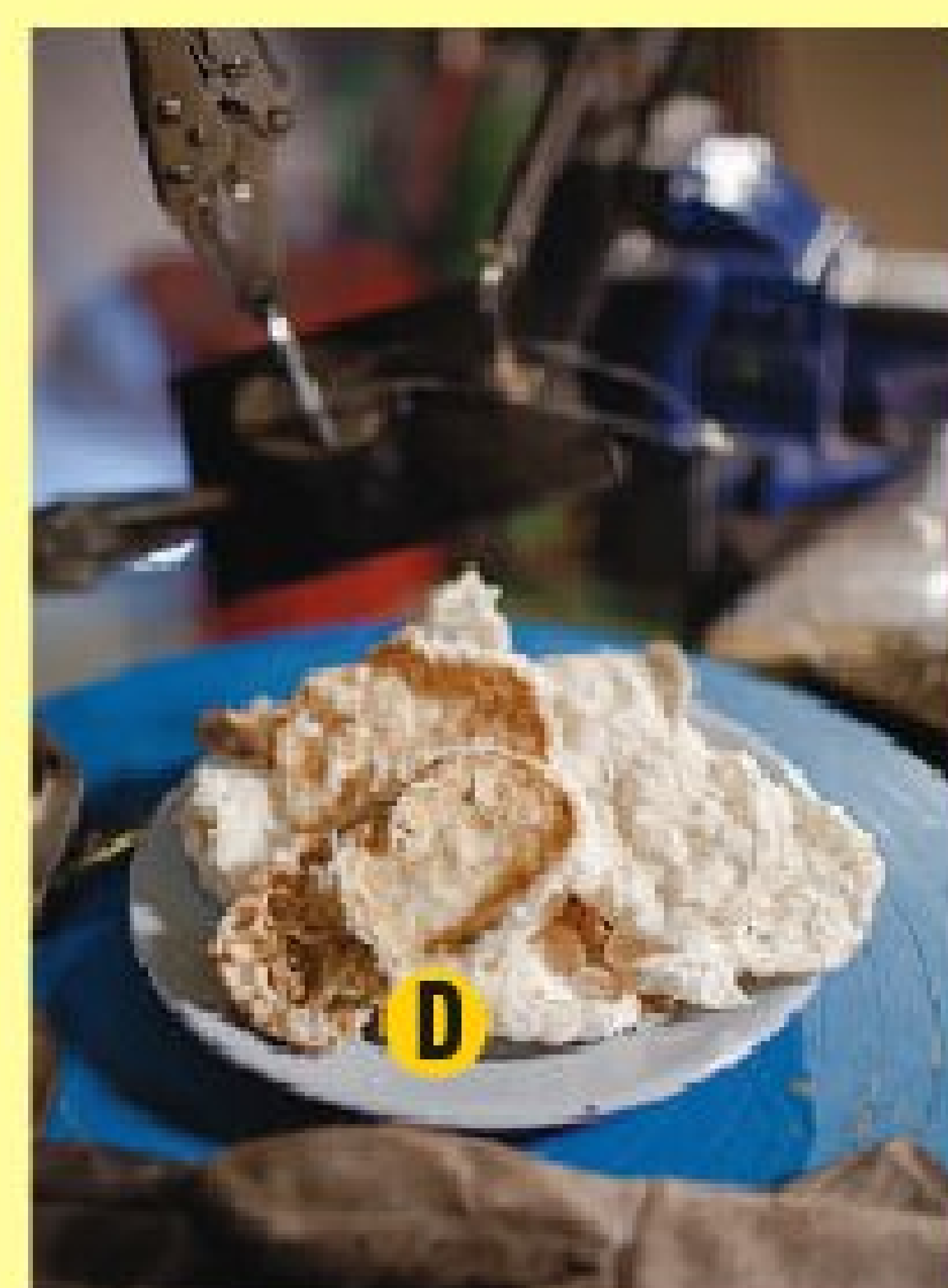


**4** Screw an eyebolt or U-bolt [B] into a piece of round stock for a handle and as a tether point for safety—when a rice cake pops, the round stock can fly too. It's best if all heated surfaces are tethered to the base with a steel cable. We used old bicycle brake cable and ferrules to secure it.



**5** Apply high heat to burn oils off, wash, and then reheat and season with frying oil, as with a cast-iron pan. This helps prevent the puffs from sticking.

**6** Load up the hot puffer with moistened grain [C]. Drop in the hot round stock, and clamp it hard with pliers (working around with a second pair improves the starch cross-linkage) for 8 to 15 seconds, depending on the grain and temperature. Release suddenly, allowing the cake [D] to fly out, or pop it out with a fork.



For more details and a video of the build, go to [popsci.com/visecakes](http://popsci.com/visecakes).



## HOW 2.0 ASK A GEEK

## WHAT CAN I DO WITH DROPBOX?

**Plenty.** At its core, Dropbox ([dropbox.com](http://dropbox.com)) is a free service that allows you to store up to two gigabytes of data in a folder that resides on the company's servers—and any other place you need it. The folder syncs to your computer, smartphone and other Web browser-equipped devices. There's nothing to configure, and it's surprisingly fast.

But there's a lot you can do with Dropbox beyond just backing up your files. You can use it to quickly sync files between your devices, and, since it's available anywhere, it provides an easy way to get a hold of information on the go. For example, you can upload recipes or shopping lists to access later on your phone at the grocery store, store nutritional information for restaurant menus in a PDF file for reference while



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[howtogeek.com](http://howtogeek.com).

dining out, or print important receipts to a file for safekeeping. To ensure security, all your files are encrypted; even Dropbox employees can't get at them.

If you want to get more geeky, store portable applications in your Dropbox folder that don't require installation. TiddlyWiki ([tiddlywiki.com](http://tiddlywiki.com)), which lets you create your own personal wiki—an editable Web page used for storing notes, links and other information—is an especially useful one. And be sure to keep Firefox, VLC and KeePass in the folder, so you can use your preferred browser, store your passwords, or play your media on any computer.

DOUGLAS FRASER

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✓Yes



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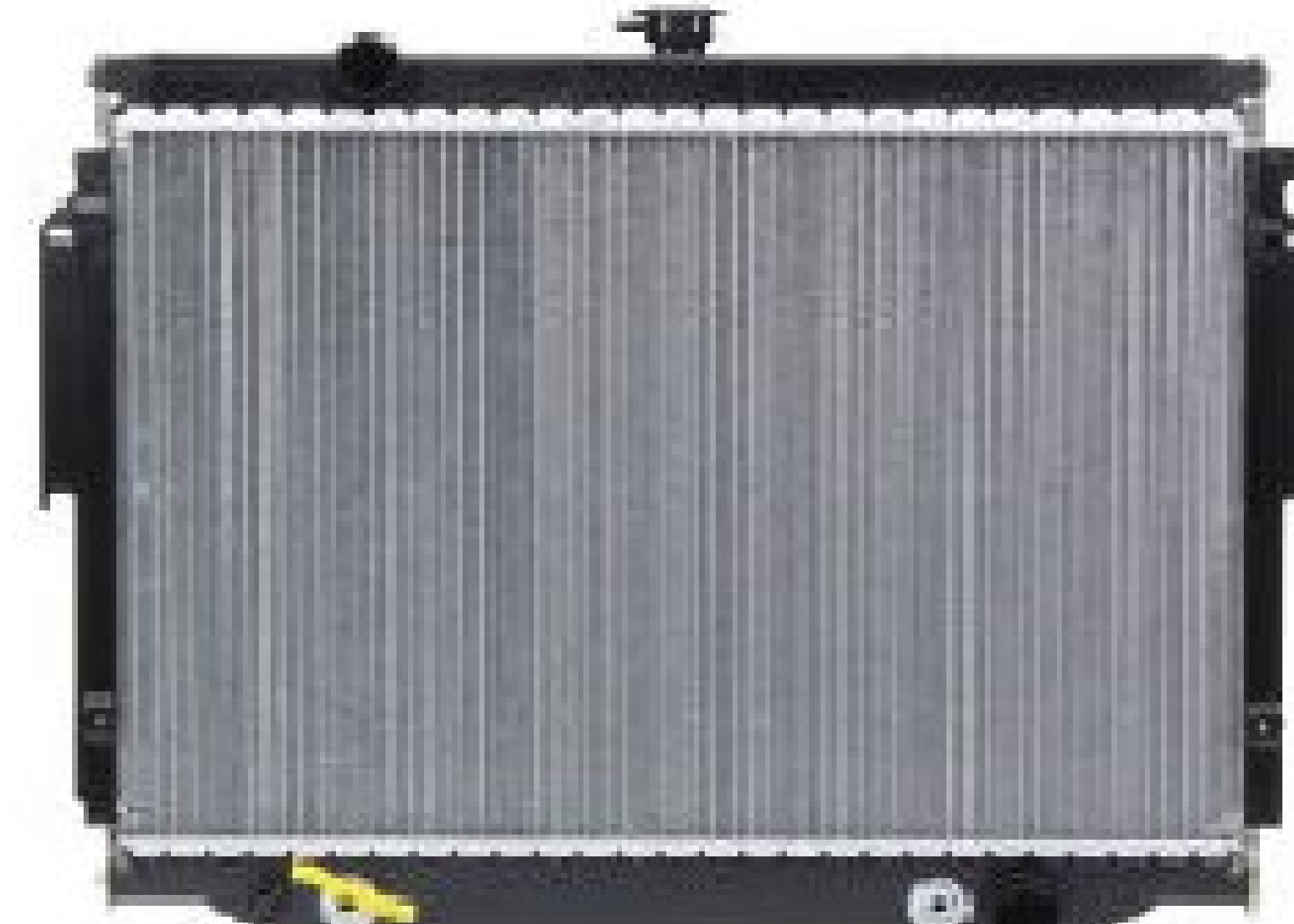
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## WEBSITE OF THE MONTH

## DIYORNOT

Even we here at How 2.0 headquarters must admit that doing a project yourself isn't always the best choice. *DiyorNot.com* helps you make an informed decision. The site estimates how long it would take you, compared with a professional, to complete home-improvement projects and tells you what the cost difference would be for parts and labor. You can even adjust the predicted costs for your zip code based on data from retailers in your area.

\*Thanks to Chris Chlasciak for project idea and photographs

## SIMPLE PROJECT OF THE MONTH

## A QUICK METAL LAPTOP STAND\*

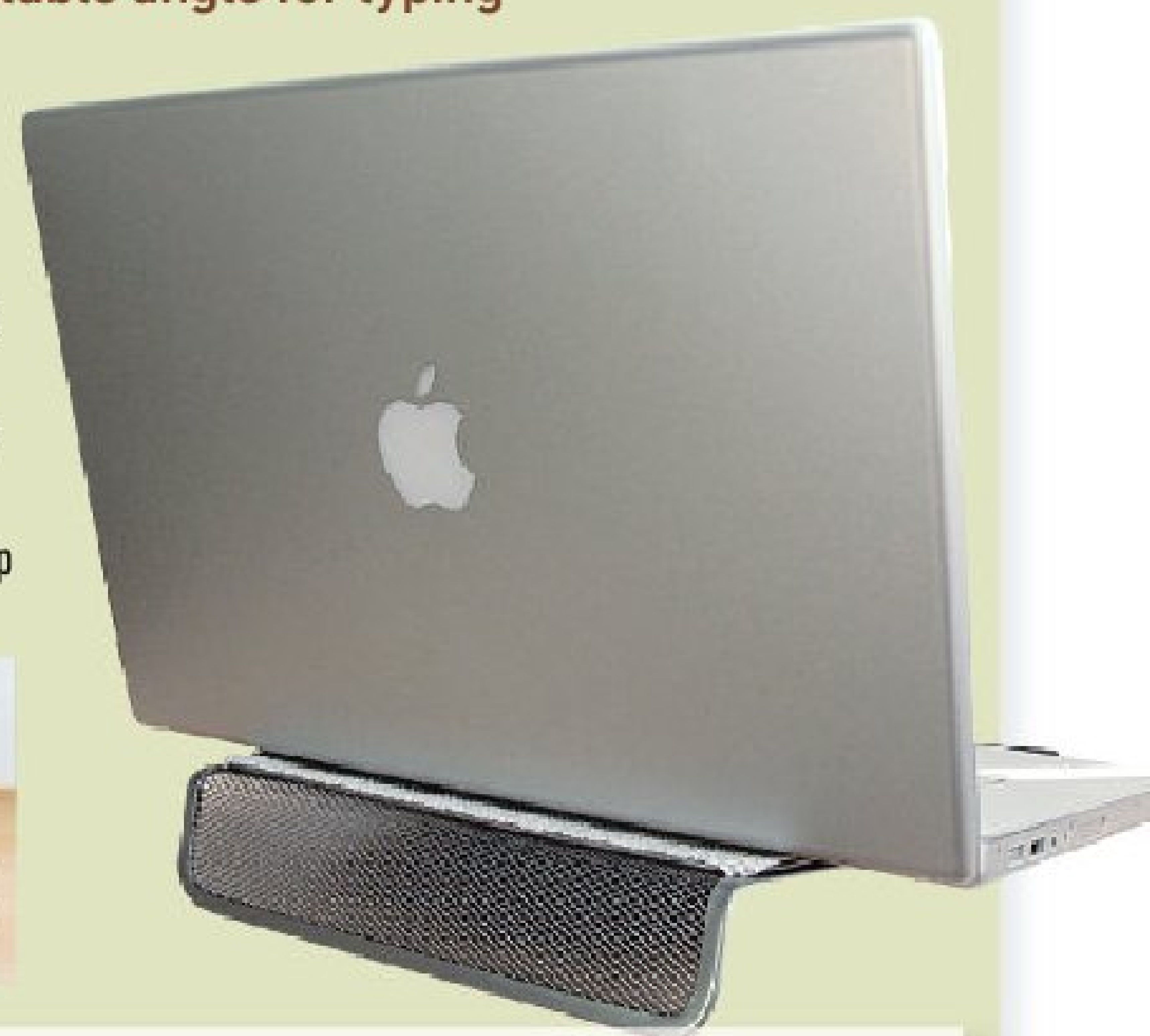
An easy and inexpensive stand made from a metallic document holder that keeps your computer ventilated and at a comfortable angle for typing

**1.** Bend the long sides of a metal mesh document holder so that one is lying flush on top of the other.

holder with double-sided tape. This will prevent the laptop from slipping and getting scratched.

**2.** Cut two blocks of rubber, and glue them onto the end of the top side of the document holder. Next, attach three strips of 1.5-inch-wide shelf liner to the edges of that side of the document

**3.** Place the stand on a desk with the rubber blocks and the shelf liner face-up, and put your laptop on it. For more details on the project, search for "metallic laptop stand" on *instructables.com*.



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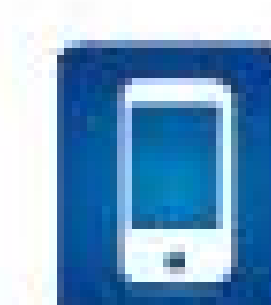
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When will we  
evolve out of use-  
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ASTRO WHIFF Space  
is full of smells, but  
mostly the burning  
odor of hydrocarbons.

# WHAT DOES SPACE SMELL LIKE?

**A** The final frontier smells a lot like a Nascar race—a bouquet of hot metal, diesel fumes and barbecue. The source? Dying stars, mostly.

The by-products of all this rampant combustion are smelly compounds called polycyclic aromatic hydrocarbons. These molecules “seem to be all over the universe,” says Louis Allamandola, the founder and director of the Astrophysics and Astrochemistry Lab at NASA Ames Research Center. “And they float around forever,” appearing in comets, meteors and space dust. These hydrocarbons have even been shortlisted for the basis of the earliest forms of life on Earth. Not

surprisingly, polycyclic aromatic hydrocarbons can be found in coal, oil and even food.

Though a pure, unadulterated whiff of outer space is impossible for humans (it’s a vacuum after all; we would die if we tried), when astronauts are outside the ISS, spaceborne compounds adhere to their suits and hitch a ride back into the station. Astronauts have reported smelling “burned” or “fried” steak after a space walk, and they aren’t just dreaming of a home-cooked meal.

The smell of space is so distinct that, three years ago, NASA reached out to Steven Pearce of the fragrance maker Omega Ingredients to re-create the odor for its training simulations. “Recently

we did the smell of the moon,” Pearce says. “Astronauts compared it to spent gunpowder.”

Allamandola explains that our solar system is particularly pungent because it is rich in carbon and low in oxygen, and “just like a car, if you starve it of oxygen you start to see black soot and get a foul smell.” Oxygen-rich stars, however, have aromas reminiscent of a charcoal grill.

Once you leave our galaxy, the smells can get really interesting. In dark pockets of the universe, molecular clouds full of tiny dust particles host a veritable smorgasbord of odors, from wafts of sweet sugar to the rotten-egg stench of sulfur. —LIZZIE SCHIFFMAN



### How much can a human body sweat before it runs out?

It all depends on the size, physical fitness and hydration of the person in question, but it's possible to sweat buckets before heatstroke sets in and we pass out. After all, there are about three million sweat glands on the human body (the highest concentration is on our palms), and the average person aggressively working out perspires about 0.7 to 1.5 liters per hour. Theoretically, if we were attached to a treadmill and pumped full of liquids, it's possible to keep sweating forever.

Particularly active people sweat about 1.5-1.8 liters an hour, while a triathlete can produce nearly four liters of sweat in the same time. During the Ironman Hawaii, competitors perspire some 15 liters (about four gallons) throughout the combined marathon run, 2.4-mile swim and 112-mile bike ride. Lawrence Spriet, an exercise physiologist at the University of Guelph in Ontario, says that after losing 3 to 5 percent of our body weight, the sweating process begins to slow down.

Lawrence Armstrong, an environmental and exercise physiologist, has proved that the human body continues sweating no matter how dehydrated it is. As long as the hypothalamus sends nerve impulses to the sweat glands, we'll perspire. If sweating stops, then something is terribly wrong.

If our core temperature goes above 104°, the body begins to overheat to the point where its proteins denature. When this happens, "membranes of the tissues lose their integrity, and things leak out," Spriet says. The intestines can discharge bacteria into the bloodstream, and the body goes into shock. But by then we would probably be unconscious, maybe even in a coma. The whole point of sweat, of course, is to prevent this from happening by keeping us cool. But even while our innards ooze, we may

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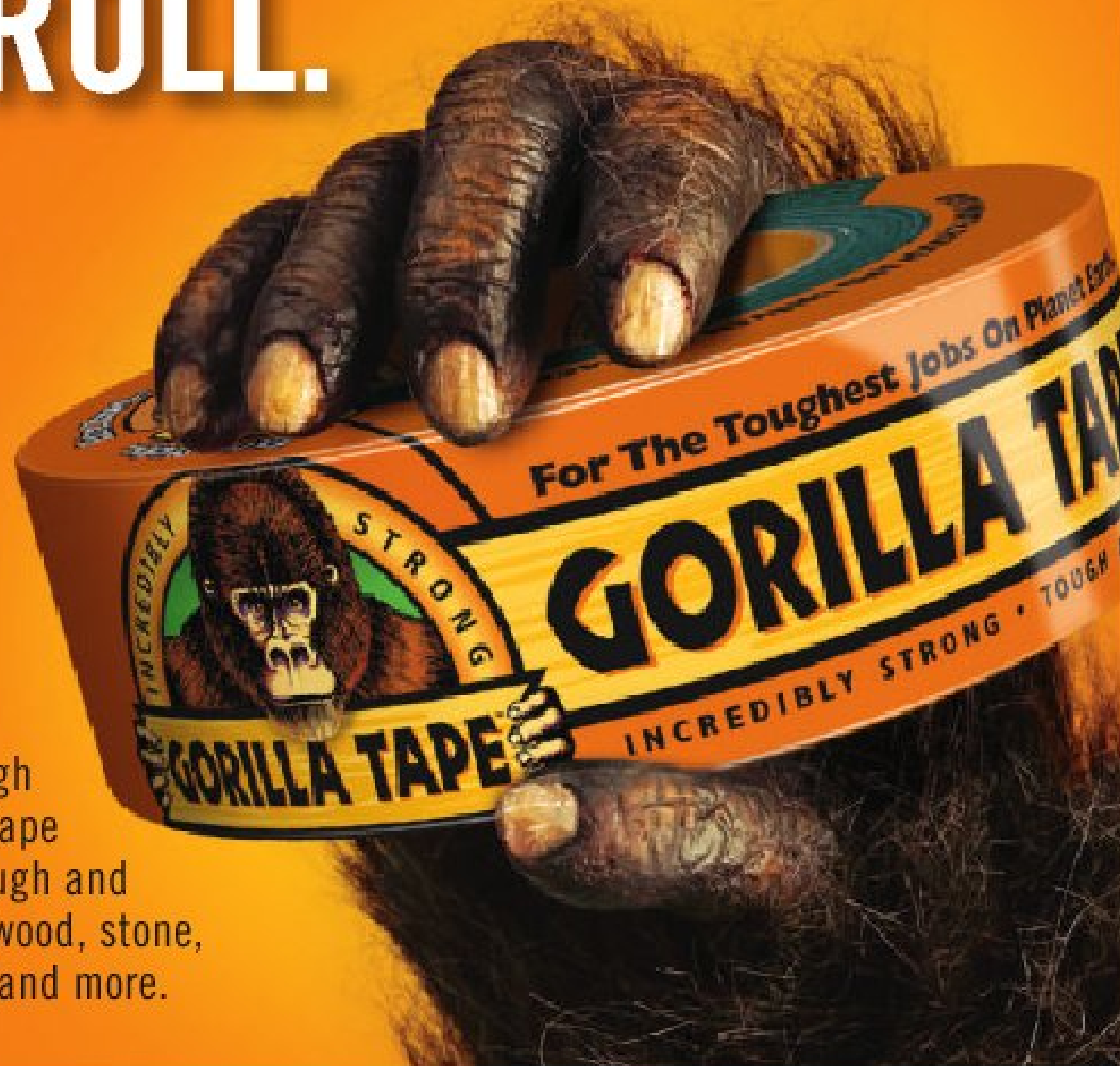
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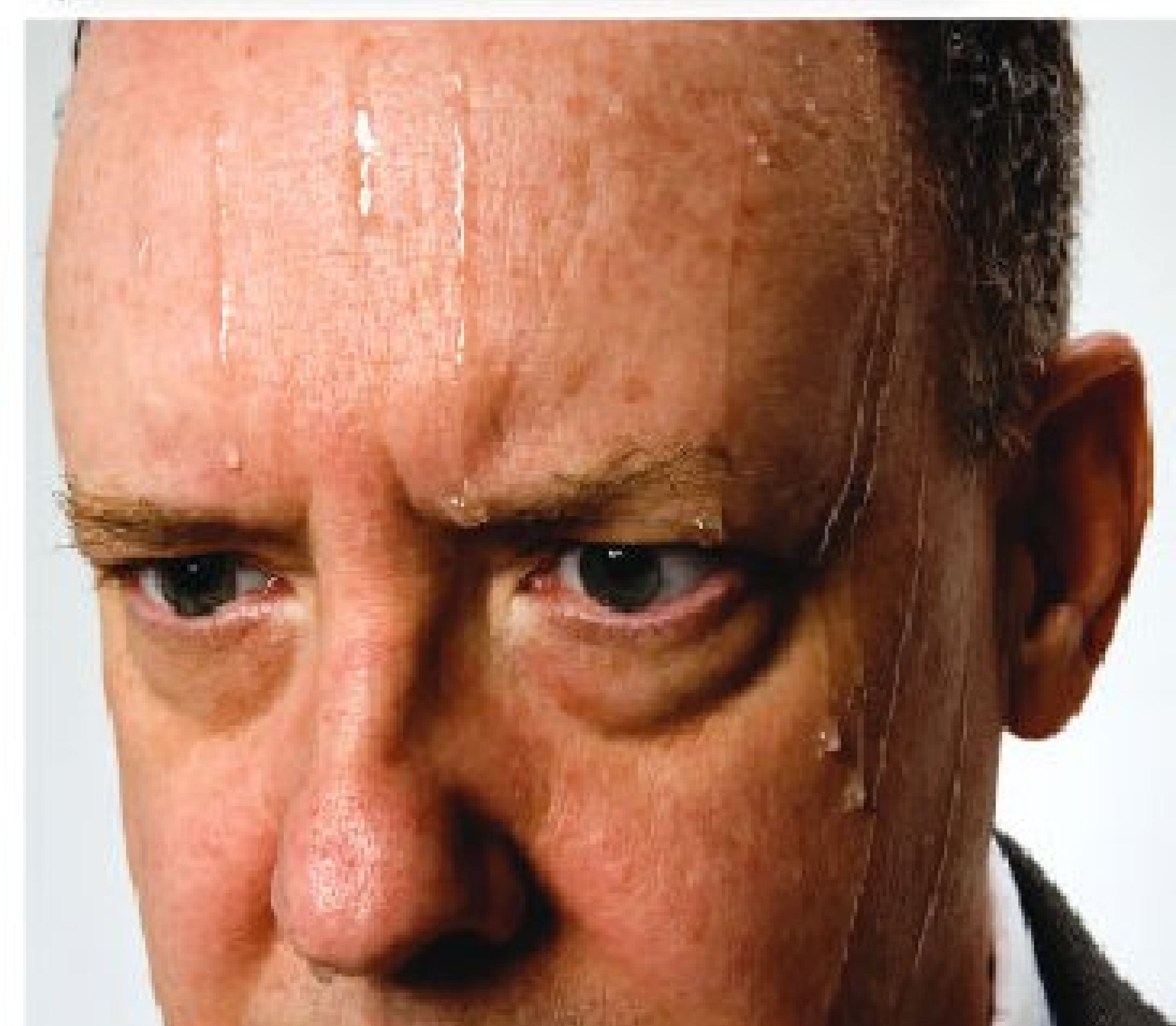
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still perspire. As Armstrong points out, it's impossible to sweat out all the water in our bodies: "People don't shrivel up until they are dead."—JULIE BECK

### When will we evolve out of our useless appendages?

Never. We're probably stuck with our appendix, pinky toes, tailbone and just about all of our other evolutionary holdovers. Wisdom teeth may eventually go, but major changes like losing an appendage (teeth included) take millions and millions of years—who knows if humans will even be around that long. What's more, most of our seemingly useless vestiges are actually helpful.

The coccyx, or tailbone, "is an attachment point of a number of muscles at the pelvis. We need it for upright locomotion. It would be catastrophic if it went away," says Kenneth Saladin, an anatomist and physiologist at Georgia College and State University. The appendix, which helped our distant ancestors digest grass, has slowly evolved to take on a new purpose. Research led by William Parker and R. Randall Bollinger of Duke University has shown that the appendix now serves as a kind of "safe house" for the microbes that aid in digestion. "Each of us has 900 to 1,600 species of bacteria in our gut to make sure we have a healthy immune system," says Stephen

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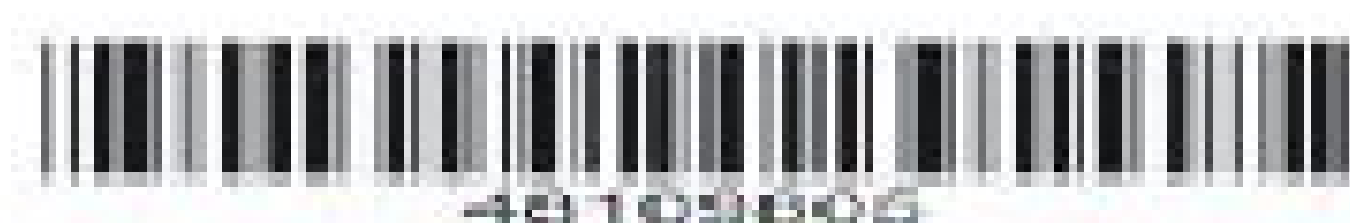
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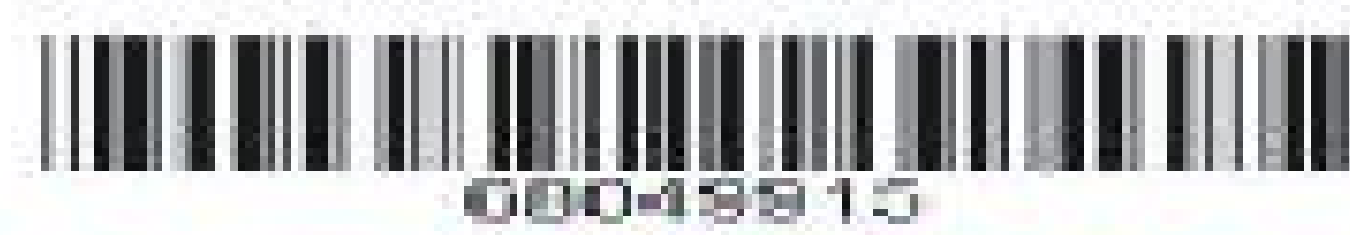
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Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually a compilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in

the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of \$10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.

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GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagra, passed his drivers test and is hardly ever home when we call - GHR delivers.

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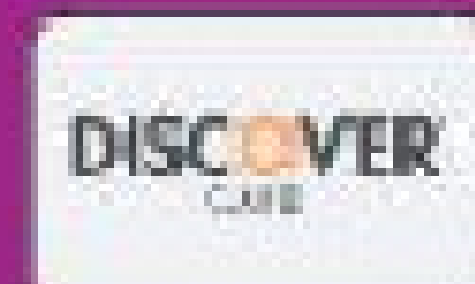
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FYI

Stearns, an evolutionary-biology professor at Yale University. "If one takes over, or they all get flushed out by a disease, then the appendix works like a holding tank for the good bacteria." Even the pinky toe helps keep our balance and diffuses impact throughout the foot when we run.

There are only a handful of truly useless parts of our body, but these are hanging on too. As Saladin puts it, "since vestiges like the muscles behind our ears have very little impact on reproductive success, there's no way to select against them." In other words, the ability to ear-wiggle doesn't interfere with having kids. Wisdom teeth were, like the appendix, good when we were eating lots of plants, but today only about 5 percent of us have jaws large enough for these extra molars. "Wisdom teeth are probably on their way out," Stearns says, "but it will take a long time."

The silliest of all vestiges is the male nipple. "Those don't have a function," Stearns says, "but they won't disappear either." All embryos, male and female, begin developing according to the female body plan. Only around the sixth week of gestation do the genes on males' Y chromosomes kick in. "The basic developmental plan has the two nipples there, so you can't get rid of them genetically because that would mess up the breasts of females." And nobody wants that.

—NATALIE WOLCHOVER ■



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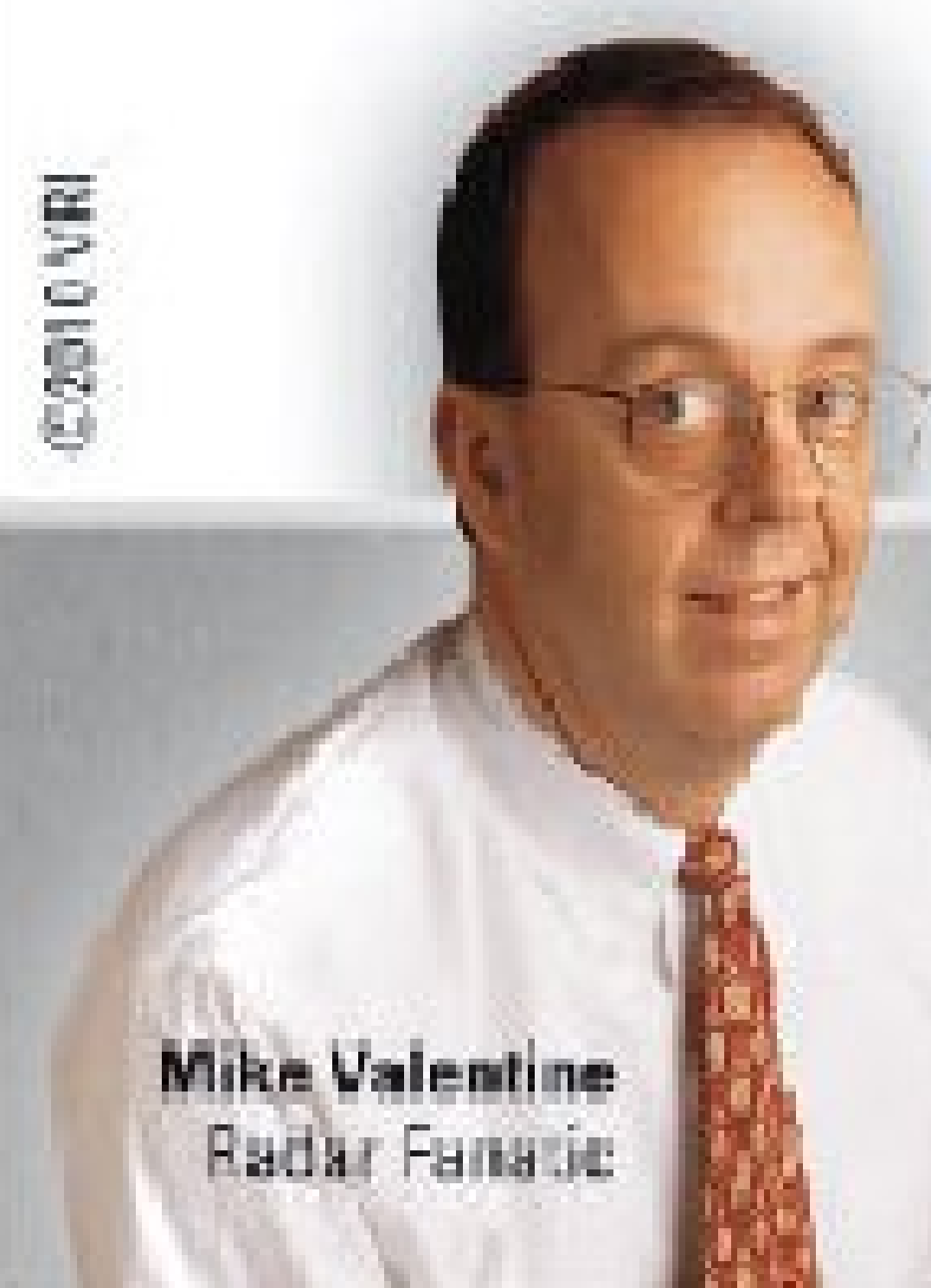


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[CONTINUED FROM PAGE 59]

# THE POWER BROKER

private funding. Then everyone heads for a nearby meeting room. As Majumdar tucks into a box lunch, another MSU professor updates him on an Arpa-E-funded bioreactor. The joint project with MIT deploys hydrogen-eating bacteria to convert carbon dioxide into liquid transportation fuels. Majumdar seems to require no catch-up on the project. He nods and asks questions, he shakes hands with everyone, and then it's time to leave. He has another visit to make nearby.

**A QUIET, GOVERNMENT-FUNDED** grant program has created technical revolution before. Consider the history of the Internet. In 1963, Arpa gave a group of MIT researchers \$2.6 million to develop a computer time-sharing system. That early work eventually evolved into Arpanet, the first wide-area packet-switching network, which, in turn, became the Internet. More than 30 years later, that \$2.6-million investment has led to an Internet economy worth at least \$250 billion in the U.S., according to the Organization for Economic Cooperation and Development. Advertising-supported online businesses alone employ 1.2 million Americans, according to a 2010 study funded by the Interactive Advertising Bureau.

Dozens of countries are now vying to dominate the clean-energy market, expected to be worth \$2.2 trillion by 2020, and the U.S. needs to do something radical to compete. This country spends about \$4 billion in public-energy research and development (not counting Recovery Act spending), compared with Japan's \$3.1 billion and Europe's \$3.3 billion. But that number is misleading. The U.S. ranks far lower when national commitment to energy R&D is measured as a percentage of GDP. Japan, Korea, France and China all spend a higher fraction of their GDP on energy research than the U.S. And China, which last year became the world's biggest overall investor in energy-efficient technology, plans to sink an average of nearly \$74 billion a year into energy R&D over the next decade in a bid to become

the world's biggest developer and manufacturer of clean-energy technology.

Arpa-E's influence will be measured in terms of barrels of oil saved, tons of CO<sub>2</sub> kept out of the atmosphere, percentage increases in solar efficiency, and boosts in the energy density of batteries. And because Arpa-E money is seed money, intended to get a prototype built that will entice follow-on funding from the private sector, projects will often need a decade to shake out as successes or failures.

Majumdar is on what seems to be a typical phone call as we drive. "Uh-huh," he says into the phone. "If they claim they can reduce the cost of PVs [photovoltaics] by half, have they provided the calculations? If not, they need to get them to us, and let's have a look." He closes his phone and turns toward me. "Right now, solar photovoltaics cost \$8 to \$10 per watt, installed," he says. "We can get that down to a dollar in 10 years with business as usual. But if we get there in five years, America's ahead of the game."

## MAJUMDAR'S SECOND STOP

today is the General Motors Research Lab in the Detroit suburb of Warren. Arpa-E dollars have found their way to university researchers and start-up companies, but it turns out there are researchers at major companies, such as GM, whose most creative ideas don't get much corporate backing. "Big companies are often technically sound but not super-innovative," says Majumdar as we pull into the campus.

The Research Lab, where 16,000 GM engineers, designers and technicians work, has housed the company's most audacious engineering efforts for more than 50 years. We meet Alan Browne and Jan Aase in the lobby of the R&D building. Aase directs GM's Vehicle Development Research Laboratory, and Browne is leading the development of the company's Lightweight Thermal Energy Recovery (LighTER) system. About 60 percent of a fuel's energy goes into the water jacket or out of the tailpipe, Browne and Aase explain. Their

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## THE OBSESSIVES

## THE POWER BROKER

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The LighTER system uses a stretched wire made of what's called a shape metal alloy—a blend of nickel and titanium—that shrinks when heated and expands when cooled.

"In a hybrid system, a loop of this wire could be used to drive an electric generator to charge a battery," says Browne as we walk to the lab. "In a conventional engine, it could even replace the alternator, without any load on the engine."

The contraption at the end of the table, a neat mass of coiled wire and sprockets, looks like some kind of perpetual-motion machine. Browne passes out safety glasses and fires up a heat gun to simulate the temperature inside a typical exhaust pipe. Just like that, the machine starts to move, pulling itself through the large pulleys as the cables shrink and expand. I reach out and try to stop one of the axles with my hand, but I can't—it's too powerful.

"We've exceeded the highest reported power output for any thermal-harvesting device," Browne says to Majumdar, proudly. "But the big challenge is the cooling side. I know you have a background in heat transfer, so if you have any ideas on the flight home about how to cool it quickly. . . ." It's the sort of thing a grantee might say to flatter his benefactor before saying

goodbye, but Majumdar springs from his chair and heads for the chalkboard. "I'm thinking you want to introduce some turbulence!" he says. Grabbing a hunk of chalk, Majumdar fires off questions—How can we maximize thermal transfer? What wire shape would shed heat fastest? What about the shape of the box?—scribbling, theorizing. Within minutes, he's debating various options with Browne and his team.

The younger engineers, who were ready to file out of the room a moment ago, stop to watch, transfixed by the performance. Majumdar and Browne trade riffs and what-ifs, brainstorming until Majumdar has filled nearly every inch of the chalkboard with calculations. "Wow," one engineer says to another, shaking his head. "It's not every day you see something like this."

Wiping chalk dust from his hands, Majumdar heads for the parking lot to begin his journey back to Washington. But the GM guys have one more thing to show him: their new hydrogen test vehicle. It's been a long day, but he gets behind the wheel. Majumdar is obviously delighted to have a tangible prototype at his command. He steers the car around one end of the Tech Center's artificial lake to a straightaway, then stomps on the throttle and careens away.

*Tom Clynes, a writer and photographer, profiled pilots who fly high-end remote-control jets in the March 2008 issue.*

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[CONTINUED FROM PAGE 69]

## The Second Green REVOLUTION

unaware that the science of agriculture is anchored in a project of for-profit genetic improvement.

At that point in the discussion, my grass-fed bison stroganoff arrived, along with our eggplant hummus pizzetas, vegetarian lasagna and an order of sweet corn *cachapas*.

"Almost nothing we eat is found in nature," Ronald said. "In a sense, it's all unnatural."

**WHEN DINNER WAS OVER**, I still had plenty of questions about our planet's prospective meals. What about that *Xanthomonas* under lock and key, I asked. Where did Xa21 rice come from? And how did gene-altered rice fit into the organic/molecular synthesis the couple envisioned?

The explanation, it turned out, was rooted in basic science. As a graduate student, Ronald had put in a request to the International Rice Research Institute in the Philippines for a sample of a hybrid cultivated from *Oryza longistaminata*, a wild species that had long been gathered by the Bela tribesmen of Mali. *O. longistaminata* tastes lousy and offers unexciting yields, but this particular variety had one thing going for it: It was virtually immune to the lesions of rice blight. Ronald and her colleagues at Cornell University—and then at U.C. Davis—spent the next five years tracking down the precise location of *Xanthomonas* resistance in the hybrid sample. She knew that if she could isolate the resistance gene, her team could eventually insert its sequence into any variety of rice they wished, from long-grained to sticky, sushi or Uncle Ben's—which was just what they accomplished in 1995, when they introduced a gene of *Xanthomonas* resistance into a once widely cultivated glutinous variety called Taipei 309 and created immunity to the ravages

of blight where none had been before, immunity that could be passed down from one generation to the next.

Just as the transnational agribusiness giants would have done with such a potentially lucrative breakthrough, Ronald and U.C. Davis filed their discovery with

the U.S. Patent and Trademark Office, thus ensuring that this genetic key to *Xanthomonas* immunity would become their intellectual property. Soon thereafter, Monsanto and Pioneer had negotiated an option to license the gene and it looked as though Xa21-enhanced seeds would ►

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## THE FUTURE OF FOOD

# The Second Green REVOLUTION

quickly enter the marketplace. But as the U.C. Davis Office of Technology Transfer haggled over the terms for returning the Xa21 gene to the International Rice Research Institute, Monsanto and Pioneer lost interest, and the commercial development of a potentially marvelous technology was frustrated. Disease resistance, it turned out, did not have the same attraction for multinationals as it did for Pamela Ronald, perhaps because Monsanto and Pioneer were already enjoying windfall profits from more lucrative agri-tech innovations, such as "Roundup Ready" crops.

Adamchak downed his last test tube of wine. "Monsanto and Syngenta are taking advantage of patent law," he said, "but I'm hoping that over time, there will be a better understanding of genes and patents and the effect on markets."

In fact, lawyers at the U.S. Department of Justice attempted to clarify some of those issues last fall, when they argued in a brief that no one can own a gene simply because it has been isolated from the rest of a genome. A gene is an element of a law of nature, they said, and a law of nature cannot be patented. But the Patent Office itself has yet to act on the briefing, and so the licensing and sale of genetically modified, mass-produced and mass-marketed seeds continues apace.

Still, just recognizing that a gene may be unpatentable is a useful first step toward achieving the long-term goal of preventing starvation. After all, it is the patent law that allows untold profits for agribusiness giants while demanding acquiescence from small farmers. It is the patent law that has complicated and delayed the commercial planting of Xa21 rice throughout the developing world. And it is the patent law that lurks behind

the inequities that have sparked the war between organic and GMO.

As long as the patent law remains as it is, the world's farmers and scientists will benefit from making intellectual property their common ground. Which is why Ronald and U.C. Davis made a special provision as it pertained to their Xa21 rice: They would make the genetic information freely available to less developed countries, while sharing any profits they or their corporate licensees might eventually earn with the impoverished African nation of Mali, birthplace of the gene. In this way, rice could be improved where improvement was most needed, and Pamela Ronald could accelerate the next green revolution. "This is a new time in science," she said. "Things are not happening fast enough."

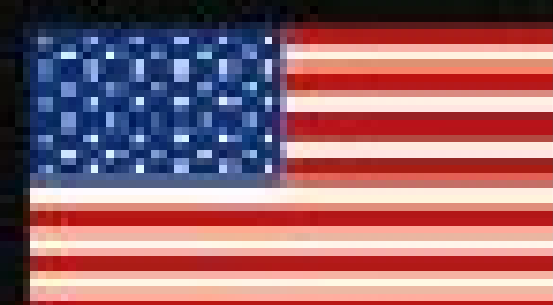
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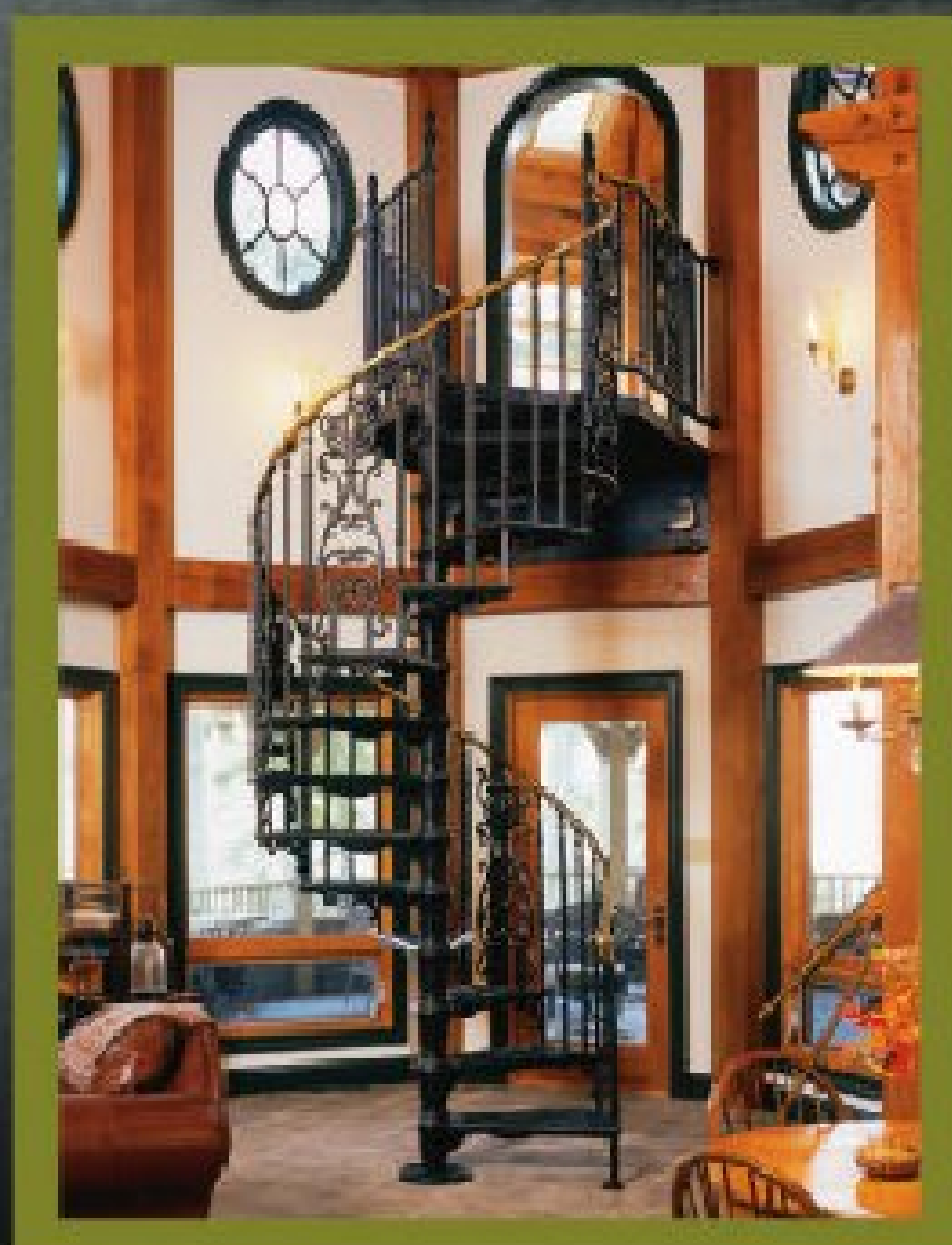
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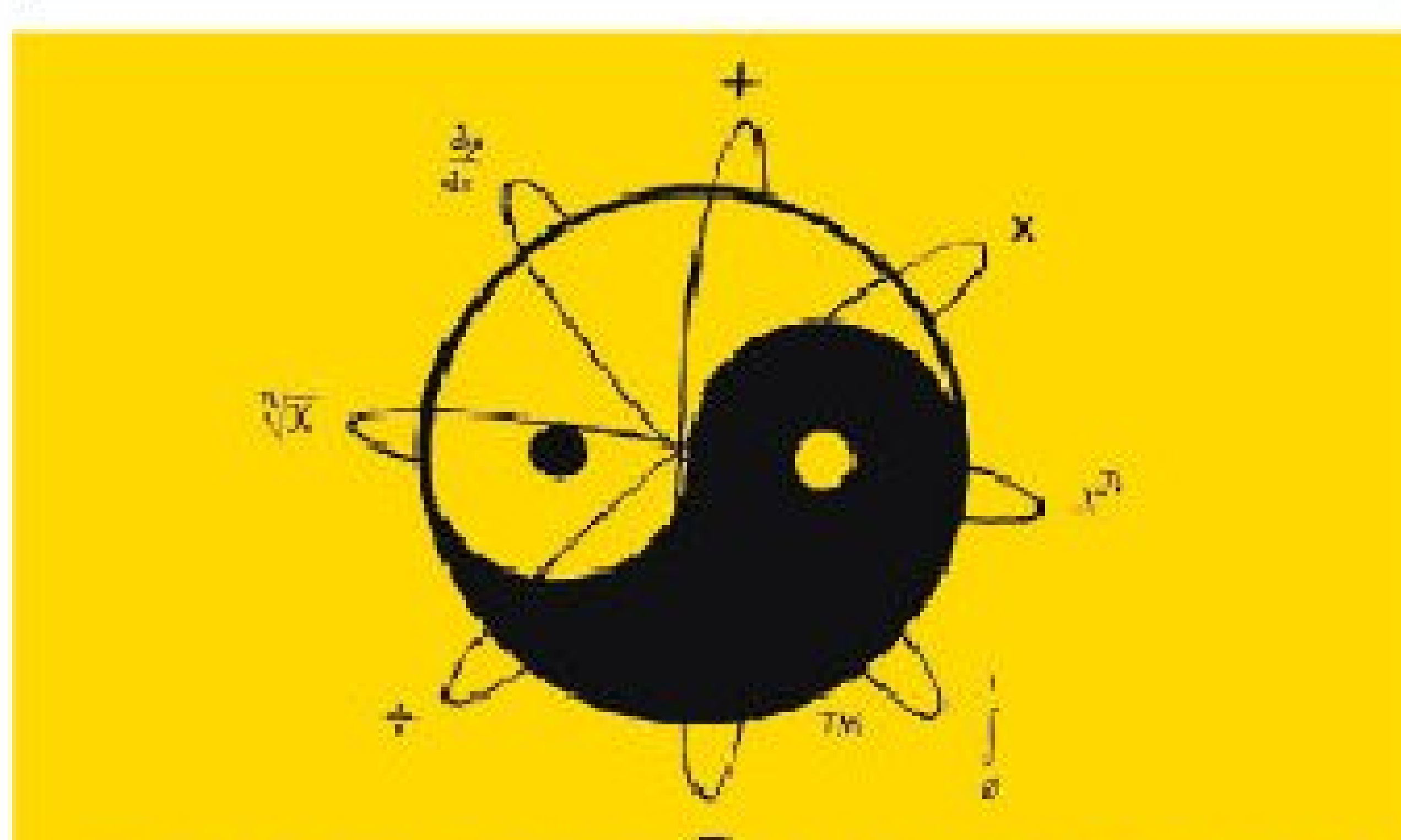
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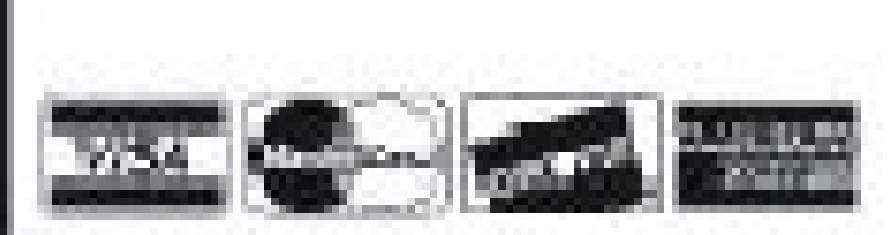
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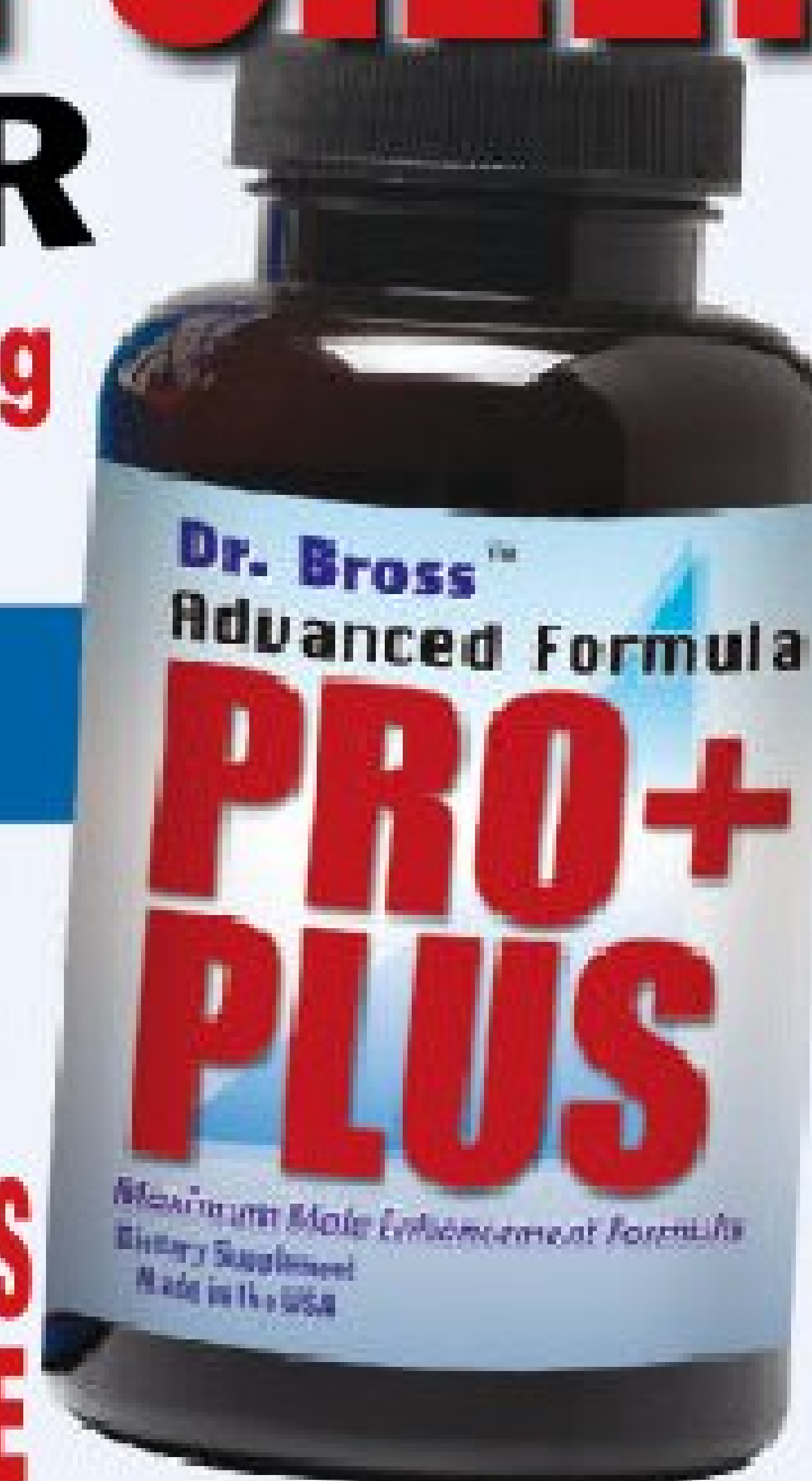
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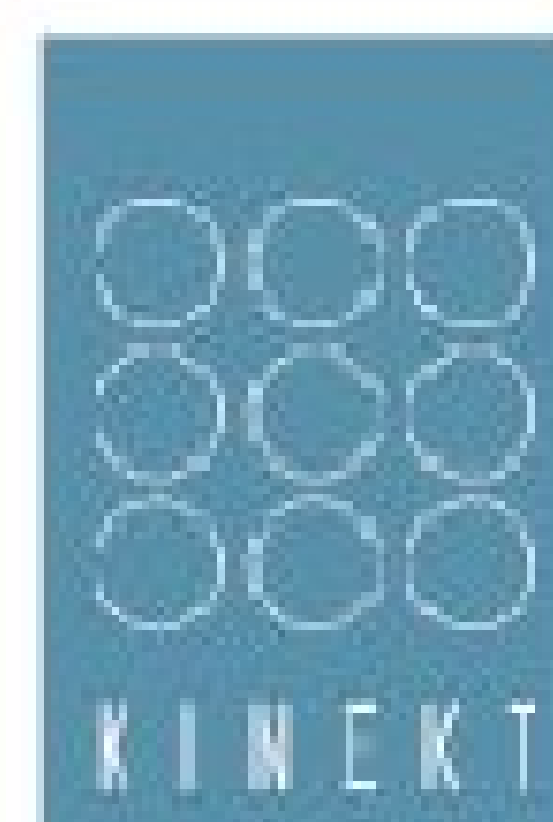
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# FUTURE THEN

THE

FROM THE POPULAR SCIENCE ARCHIVES

JANUARY 1932

## Second Wind

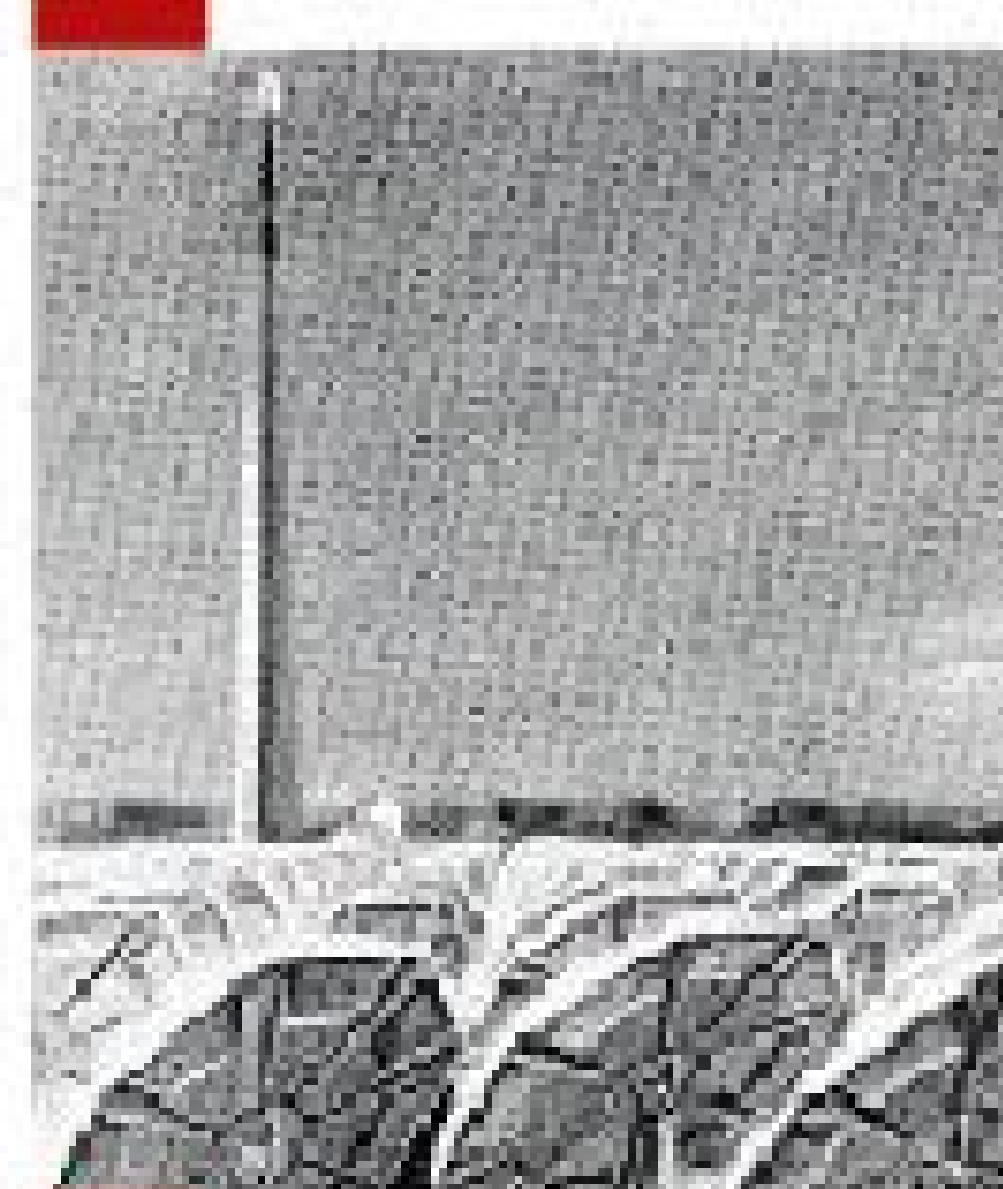
When German ships outfitted with wind-capturing propulsion cylinders arrived on American shores in 1926, U.S.-based physicists were inspired, and tried applying the technology to generate electrical power. A "merry-go-round" power plant would have employed 20 spinning eight-story cylinders that traveled around a 3,000-foot-diameter track and harvested wind power through something called the Magnus effect: The cylinders bent moving air currents around them, and the force of that air made the entire assembly rotate on its track, turning turbines to generate electricity. Six American power companies funded the construction of the first cylinder, but a plant was never built. The plant's designer, Julius D. Madaras, estimated that in 28mph winds, the mechanism would supply enough power for a city with 150,000 inhabitants, but windmill-style turbines eventually proved more efficient. To look into the new agency responsible for the most advanced energy research in the U.S., turn to page 54.

—LIZZIE SCHIFFMAN

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### Alternative Energy Solutions through the Years



October 1975

#### NOVEMBER 1944

##### Bright Idea

World War II accelerated the interest in energy-saving technologies like radiant-heat flooring. By mid-war, insulated glass helped households conserve coal.

#### MARCH 1951

##### The Wheel Deal

Switzerland introduced a bus powered by a free-spinning flywheel rather than a gas engine. A small electric motor would rewind the flywheel at each bus stop.

#### OCTOBER 1975

##### Mirror, Mirror

The U.S. government for the first time awarded contracts to develop mirrors, called heliostats, that reflected sunlight, heating water stored at the top of a 312-foot tower [left].

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